

05

## SIXTH AND SEVENTH QUARTERLY PROGRESS REPORTS

67TH QTR

"Made available under NASA sponsorship  
in the interest of early and wide dis-  
semination of Earth Resources Survey  
Program information and without liability  
for any use made thereof."

## LANDSAT FOLLOW-ON INVESTIGATION

NO. ~~21300~~  
21300

77-10087

CR-149570

- A. TITLE OF INVESTIGATION: LANDSAT Survey of Near-Shore Ice Conditions  
Along the Arctic Coast of Alaska
- B. PRINCIPAL INVESTIGATOR: Dr. William J. Stringer
- C. PROBLEMS IMPEDING INVESTIGATION: None
- D. PROGRESS REPORT:

Using LANDSAT band 7 imagery at 1:500,000 scale, preliminary near-shore ice maps prepared the previous quarter for late spring and early summer 1973, 1974 and 1975 of the Beaufort Sea coast of Alaska have been annotated and are presented here as part of Appendix A. In addition, this quarter, mid-summer 1975 Beaufort sea ice maps have been completed and are presented as part of Appendix A. These maps then complete the preparation of maps of Beaufort Sea ice conditions.

In addition, Chukchi Sea ice maps have been completed for the winter, spring and summer, 1973, 1974 and 1975 and late winter 1976 ice seasons. Half-size copies of these maps are also included as part of Appendix A. This series of maps then completes our preliminary analysis of Chukchi Sea ice conditions.

- E. INTERACTION WITH OTHER INVESTIGATORS AND AGENCIES:

We were invited to participate in a symposium of bird biologists held in Anchorage during October 1976 to provide data concerning springtime ice and open water conditions in the coastal area under study. It appears that the data generated by this contract will be of value to these biologists in determining the nesting and breeding habits of Alaskan coastal birds and help explain some wide year-to-year variations in production of birds at various rookeries.

- F. PLANS FOR NEXT REPORTING PERIOD:

During this period we will synthesize the results presented in these quarterly reports and prepare a draft final report.

- G. RECOMMENDATIONS: None

(E77-10087) LANDSAT SURVEY OF NEAR-SHORE  
ICE CONDITIONS ALONG THE ARCTIC COAST OF  
ALASKA Quarterly Progress Report (Alaska  
Univ., College.) 278 p HC A13/MF A01

CSCI 081 G3/43

Unclass  
00087

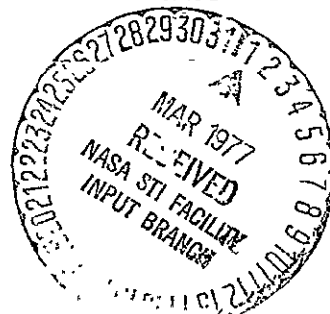
N77-17540

21300

RECEIVED

FEB 09 1977

SIS/902.6



H. PUBLICATIONS: None this reporting period.

I. SIGNIFICANT RESULTS:

See attached sheet.

J. APPENDICES:

Appendix A is attached.

SIXTH AND SEVENTH QUARTERLY PROGRESS REPORTS

LANDSAT FOLLOW-ON INVESTIGATION

NO. 21330

TITLE: LANDSAT Survey of Near-Shore Ice Conditions Along the Arctic  
Coast of Alaska

PRINCIPAL INVESTIGATOR: William J. Stringer

DISCIPLINE: Oceanography

SUBDISCIPLINE: Ice Dynamics

SUMMARY OF SIGNIFICANT RESULTS: None this reporting period.

*Original photography may be purchased from:*  
EROS Data Center  
10th and Dakota Avenue  
Sioux Falls, SD 57198

## APPENDIX A

### SYMBOLS USED AND THEIR MEANING

Listed below are the symbols used to map near shore ice conditions from LANDSAT imagery. This list of symbols has evolved during the mapping project and reflects ice conditions which can be detected on LANDSAT imagery as well as those ice conditions considered important in the understanding of near shore ice dynamics.

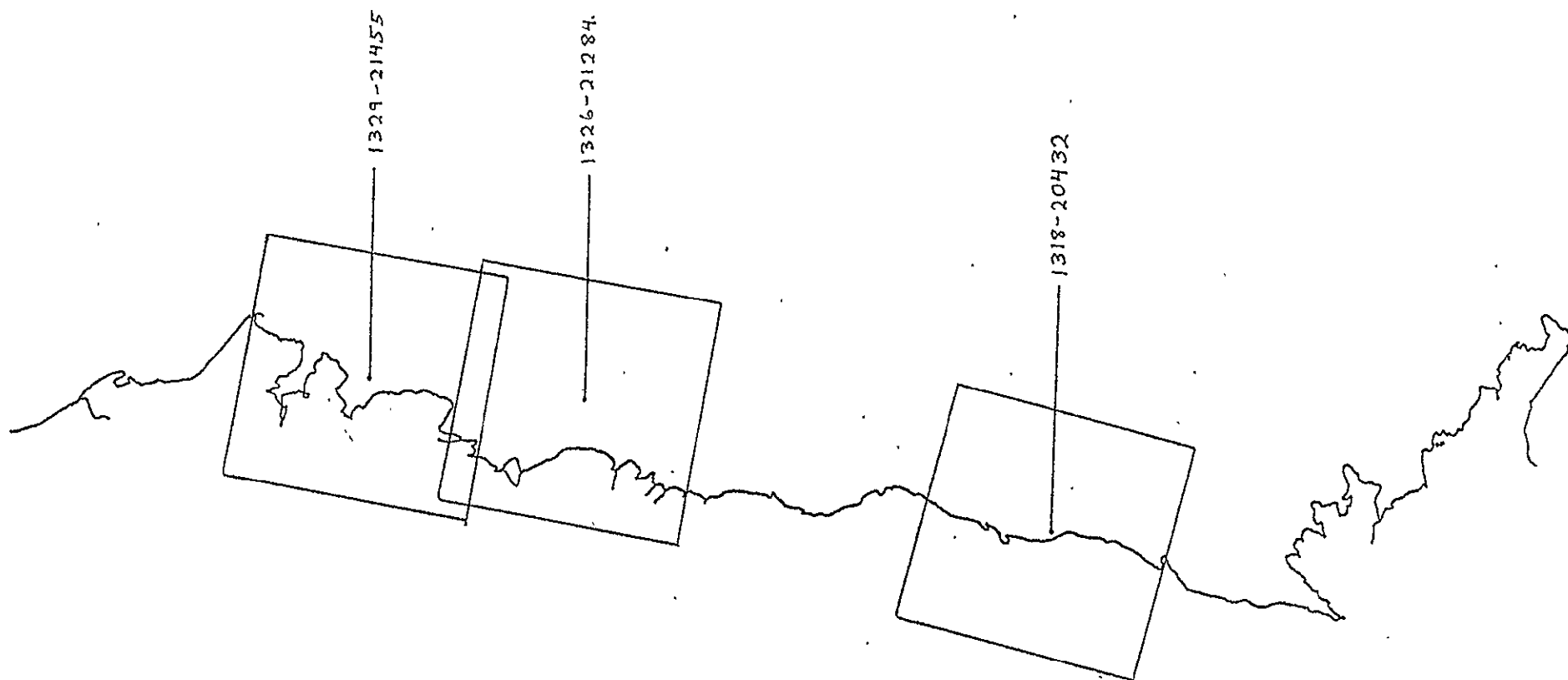
A	River Overflow	Used to denote areas where river water has overflowed onto sea ice.
B	Boundary	Denotes boundary between what appear to be two different ice types even though the two ice types may not be differentiated.
Bn	Broken New Ice	Sheet of new ice which has been broken - usually into an irregular pattern
Bpn	Broken Pans and New Ice	A sheet of young or first year ice is broken into pans followed by the freezing of the voids to the new ice stage, followed by the breaking of this entire matrix. Several cycles of this process may be evident, but the most recently-formed ice has developed to the new ice stage.
Bpy	Broken Pans and Young Ice	A sheet of young or first year ice is broken into pans followed by the freezing of the voids to the young ice stage followed by the breaking of this entire matrix. Several cycles of this process may be evident, but the most recently-formed ice has developed to the young ice stage.
By	Broken Young Ice	Sheet of young ice which has been broken - usually into an irregular pattern
C	Contiguous Ice	Ice stationary and continuous from shore without apparent fractures. This ice is at the time of observation fast with respect to the shore. The symbol is placed within large expanses of such ice and along the landward side of the seaward edge of such ice. Contiguous ice is not necessarily bounded on the seaward edge by grounded ice and can therefore extend seaward considerable distances.
Cf	Fractured Contiguous Ice	Contiguous ice which although not separated from shore by an open lead, is fractured by leads - often perpendicular to the shore.
D	Decayed Ice	Rotting or decaying ice, characterized by a dark mottled effect indicating holes and puddling.

ORIGINAL PAGE IS  
OF POOR QUALITY.

F	Floe	Separately identifiable ice floe. Symbol used to denote floes distinctly visible against background even when completely frozen into surrounding ice.
Fw	Floes in Water	Open water with numerous floes of various sizes (see "Up".)
Fy	First Year Ice	Ice cover of age and thickness beyond "young" stage. Used principally to denote large expanses of ice in either contiguous or offshore category. May be composed of single sheet, many pans frozen together, or many pans compressed, and frozen together. Thickness on the order of 30-70 cm.
Fyb	First Year Broken	A broken or fragmented expanse of first year ice.
G	Grounded	Ice which clearly appears to be grounded.
H	Hummock Field	Large expanses of piled ice.
I	Young Ice	Ice appearing light grey on LANDSAT imagery. Can be single sheet or exhibit a variety of conditions (broken, compressed, rafted etc.). Thickness on the order of 10-30 cm.
L	Lead	A lead, usually open, but may be so narrow that this can not be determined. Large leads denoted by two lines showing boundaries, narrow leads denoted by single line.
M	New Ice	Characterized by dark shade of grey, smooth texture, may exhibit a number of conditions (see I). Thickness on the order of 0-10 cm.
N	Newly Frozen Lead or Polynya	Either new or young ice. Symbol usually written within distinct boundary.
O	Old Frozen Lead	A lead with ice sufficiently old to have either turned light grey or be covered with snow.
P	Partly Frozen Lead	Partly frozen lead. Ice conditions not uniform (as distinct from M) and may vary from new ice to late stages of young ice.
Pn	Pans in Matrix of New Ice	A sheet of young or first year ice had broken into pans and the surrounding water has frozen to the young ice stage.

R	Ridge	Denotes shear or pressure ridge or system of ridges.
S	Smooth Ice	Usually used to denote ice of uncertain age in protected areas.
T	Tidal or Tension Cracks	Cracks in near shore ice opened by either tidal action or thermal tension. Identification may be indirect (snow drifts, drainage pattern etc.)
Up	Unconsolidated Pack	A broken sheet of ice of any age beyond young ice which has been compressed to the point that open water voids are quite small but are not frozen over (see FW).
W	Water	Open water. - symbol often used to denote specific area enclosed by line.
Y	Polynya	More specific than W. Most often used to denote area of open water on lee side of obstruction.
Z	Zone of Shear	Symbol used to denote location of apparent shearing motion on image. The symbol may be specifically located on a lead where shearing motion is taking place, a closed lead where shear piling of ice is apparently occurring or in an ice field where characteristic pattern of leads caused by shearing forces can be seen.

ORIGINAL PAGE IS  
OF POOR QUALITY

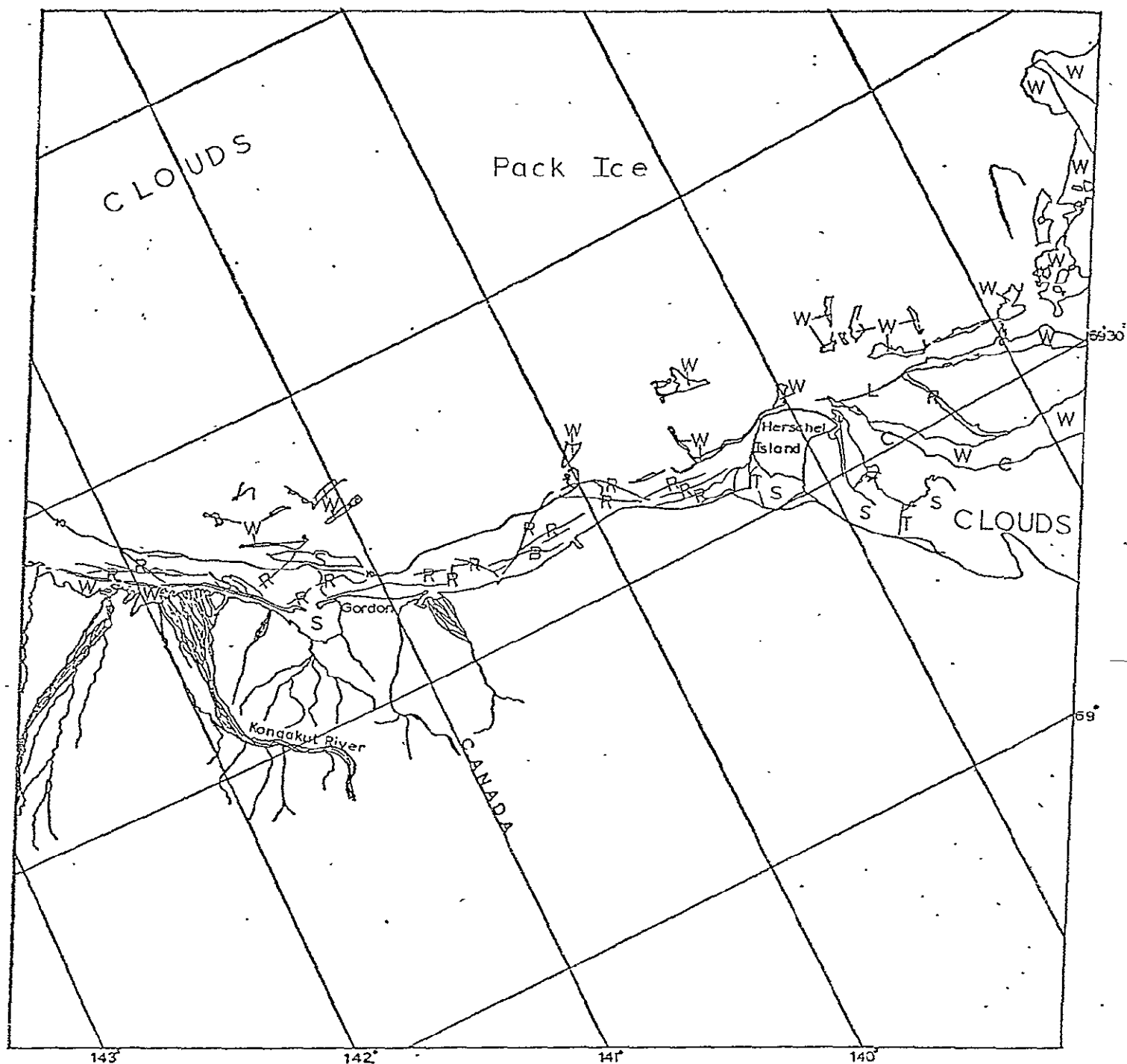


BEAUFORT SEA  
31 MAY - 17 JUNE 1973  
Images: 1312 -1329

Scene E-1318-20432

This scene shows late spring (6 June) 1973 ice conditions along the Beaufort coast from Herschel Island eastward to the mouth of the Kongakut River. The boundary between the pack ice and fast ice is not clearly defined. However, only at a considerable distance from shore are there large patches of open water presumably caused by shifting of pack ice. In the near shore area there are to be found many 1 - 3 acre melt ponds on the ice and large expanses of flooded ice. This area is crossed by many ridges and apparent fossil tension cracks located shoreward of the 10-fathom contour while the large patches of open water are located seaward of this bathymetric contour. Large leads have opened east and west of Herschel Island perhaps defining the boundary of fast ice in those locations. In the very near shore areas large expanses of open water and flooded ice can be found.





E-1318-20432-7

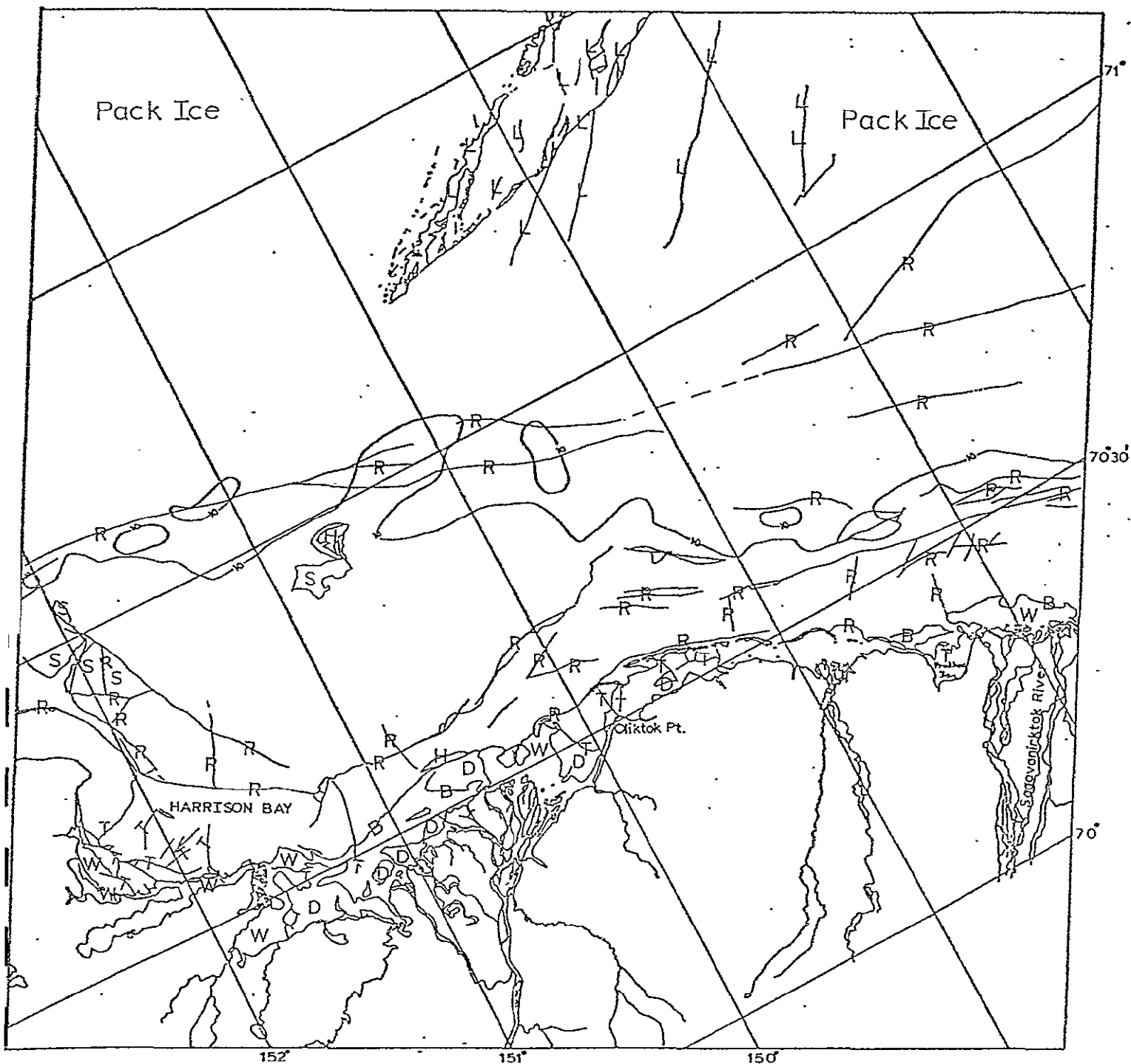
6 JUNE 1973

KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene E-1326-21284

This scene shows the portion of Beaufort coast from Harrison Bay eastward to the mouth of the Sagavanirktok River for late spring (14 June) 1973. The boundary between pack ice and fast ice is not well defined. The leads noted in the northern portion of this scene are obviously located in deep water well beyond the pack ice boundary. Two major ridge systems running roughly parallel to the coastline could be found. The first of these coincides with the 10-fathom contour across western Harrison Bay and then continues eastward in the same direction although the 10-fathom contour indents toward the coastline. The second set of ridges runs just inshore of the 10-fathom contour eastward from a point midway between Prudhoe Bay and Oliktok Point. Throughout this scene there is evidence of pressured ice, the major exception being interior Harrison Bay. In the very inshore areas the ice has either been flooded with melt water or has melted entirely.



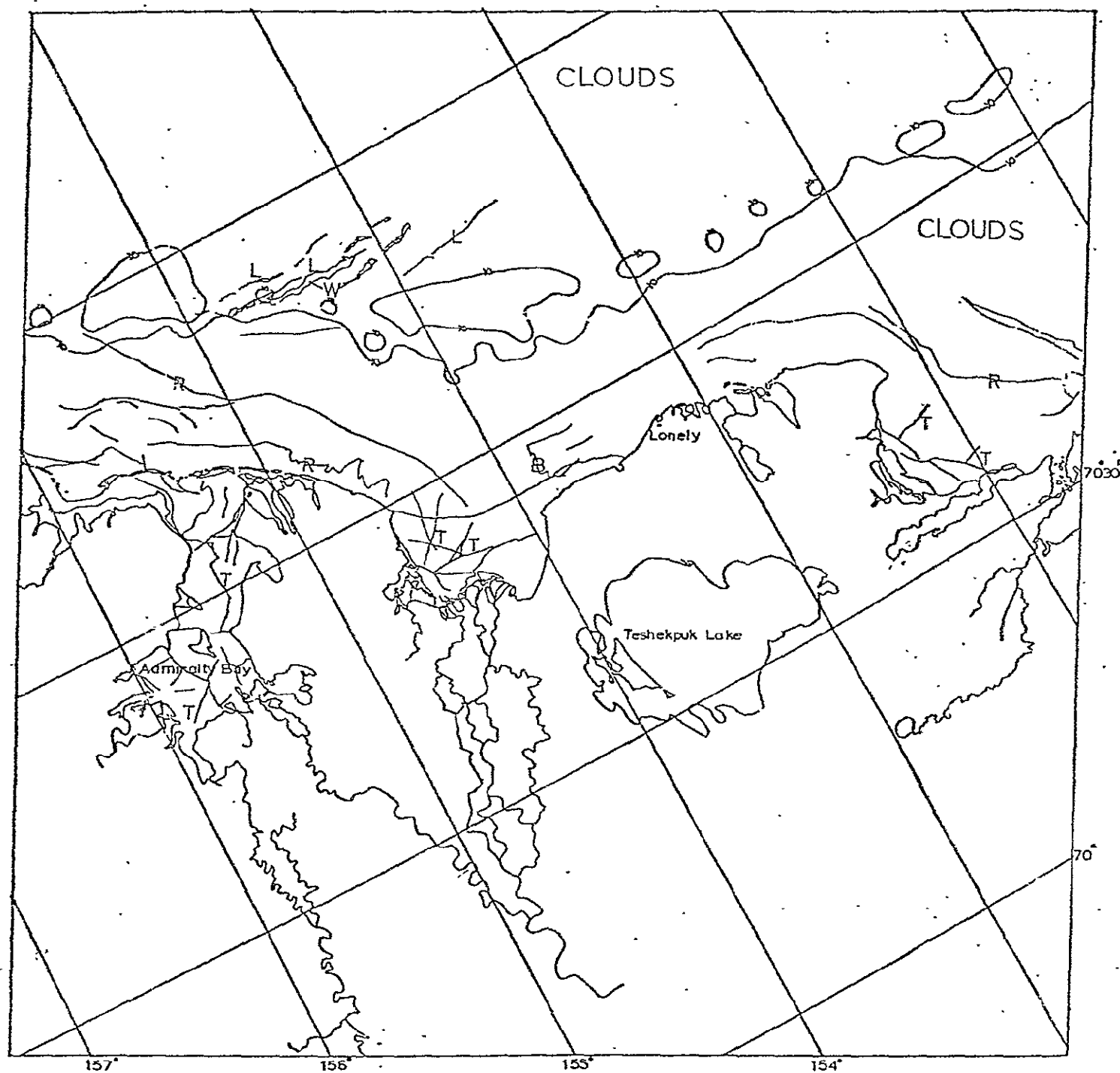
KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-1326-212847  
 14 JUNE 1973

Scene E-1329-21455

This late spring (17 June) 1973 scene shows the portion of Beaufort coast eastward from Harrison Bay past Admiralty bay. Although partly obscured by clouds, sufficient detail can be seen on this Landsat scene to map significant ice features. Although considerable ponding is evident, the only open water resulting from shifting ice lies beyond the 10-fathom contour. There is no strong evidence of major shear ridging westward of Lonely; further, there is considerable evidence of only minor pressuring during the past winter, particularly between Smith and Admiralty Bays. In the very near shore areas considerable flooding and melting has taken place: inside Admiralty Bay, only the ridges raised as a result of refreezing of tension cracks remain drained of melt water. The only clear evidence of a boundary between pack ice and fast ice is the open water resulting from shifting of broken-up and freely-floating ice located just beyond the 10-fathom contour.

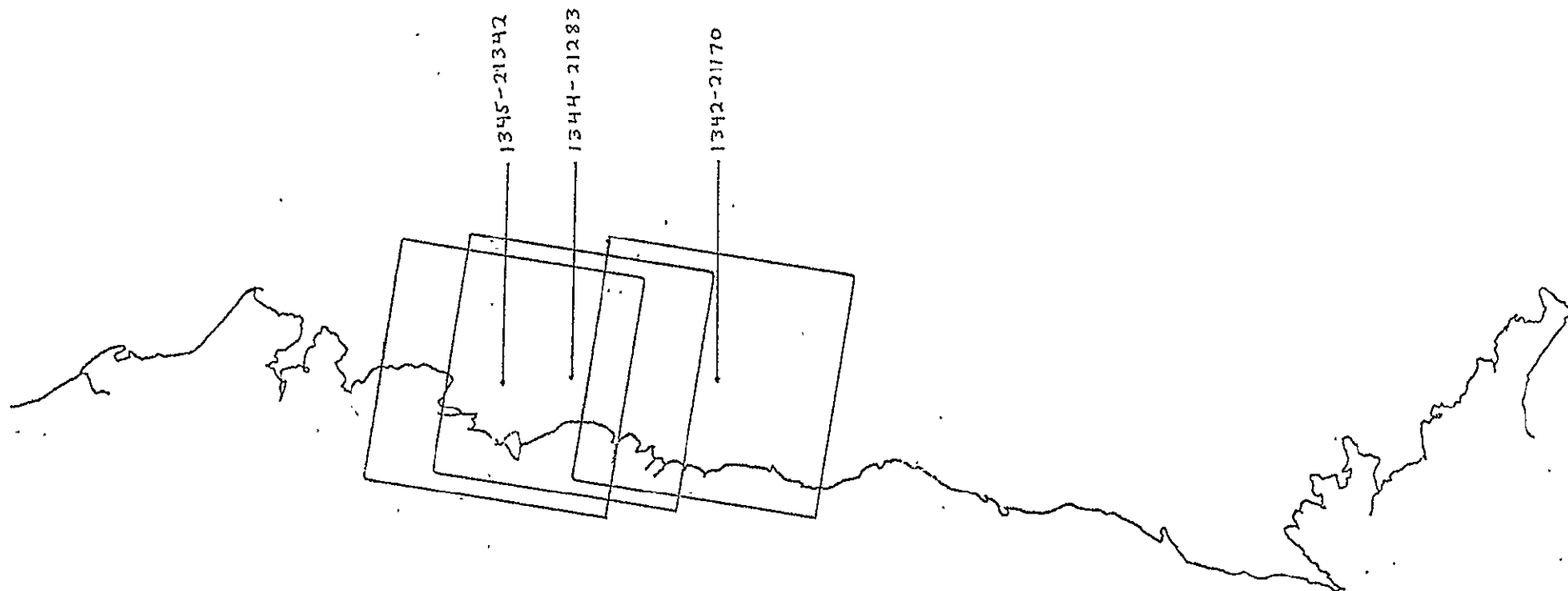


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-1329-21455-7  
17 JUNE 1973

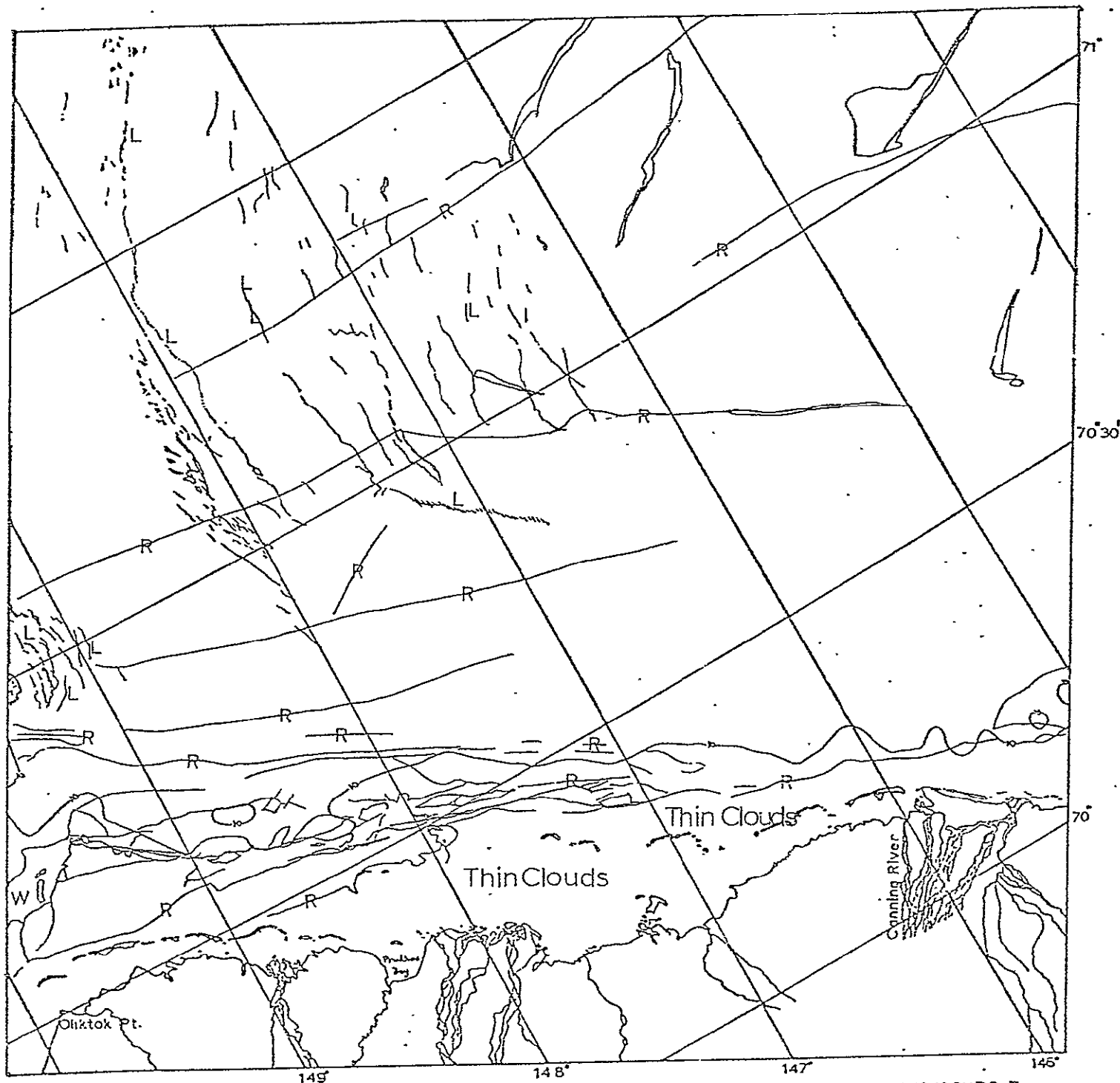
14



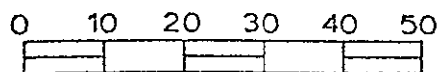
BEAUFORT SEA  
18 JUNE-5 JULY 1973  
1330-1347

Scene E-1342-21170

This end of spring (30 June) 1973 Landsat scene shows the portion of Beaufort coast between Oliktok Point and the mouth of the Canning River. This scene shows considerable evidence of past shear ridging extending from the near shore areas far seaward. The most extensive ridging has taken place in the vicinity of the 10-fathom contour between Oliktok Point and the mouth of the Sagavanirktok River, and is found between the offshore islands and the 10-fathom contour. Shoreward of the most shoreward ridge mapped there is evidence of minimal pressuring of ice during the previous winter. In the very recent past two series of concentric lead systems have developed in the pack ice. However, the pack ice is no longer a continuous sheet with the result that shifting pans are quickly making the leads into irregularly-connected patches of open water.



KILOMETERS



SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-1342-21170-7

30 JUNE 1973



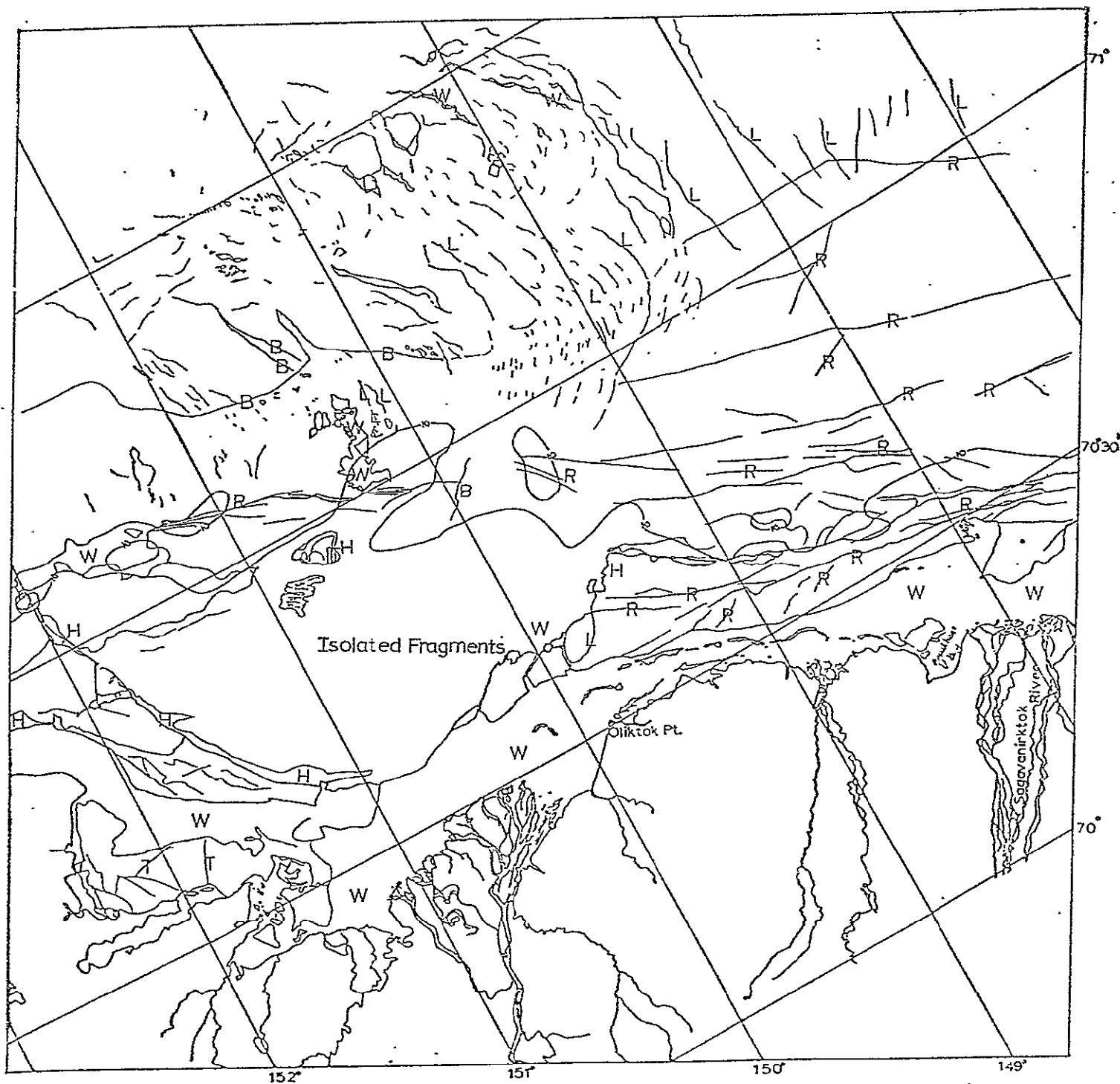
Scene E-1344-21283

This Landsat scene shows the portion of Beaufort coast between Harrison Bay and the mouth of the Sagavanirktok River for early summer (2 July) 1973. This scene allows some distinction between pack ice and grounded features. To the west from the top center of this image pack ice is fracturing in concentric rings and drifting westward. To the east of top center the polar ice sheet remains generally continuous. In this zone many large shear ridges have been mapped in ice quite seaward from the 10-fathom contour.

Nearer shore, many shear ridges can be found running roughly parallel to the shore line across the image. Some of these give evidence of being grounded: to the west of center, one group of ridges run across a raised portion of ocean floor eastward to a protruding finger of the 10-fathom contour. Seaward of these ridges is moving pack ice. However, just westward of the western terminus of these ridges is an open body of water located over another raised portion of sea floor. Presumably in this location the extensions of these same ridges have been rafted away.

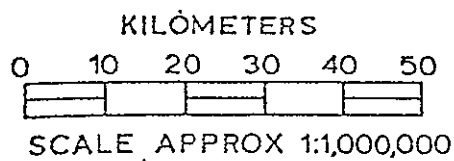
On the eastern side of the image the absence of moving pack ice does not allow determination of the polar ice-grounded ice boundary. However, it is interesting to note that there are generally two systems of ridges: one considerably seaward bridging a landward indentation of the 10-fathom contour and another series roughly parallel with the indented portion of the 10-fathom contour.

In the near shore areas, there is considerable open water resulting from spring time flooding of near shore ice by river water.



E-1344-21283-7

2 JULY 1973

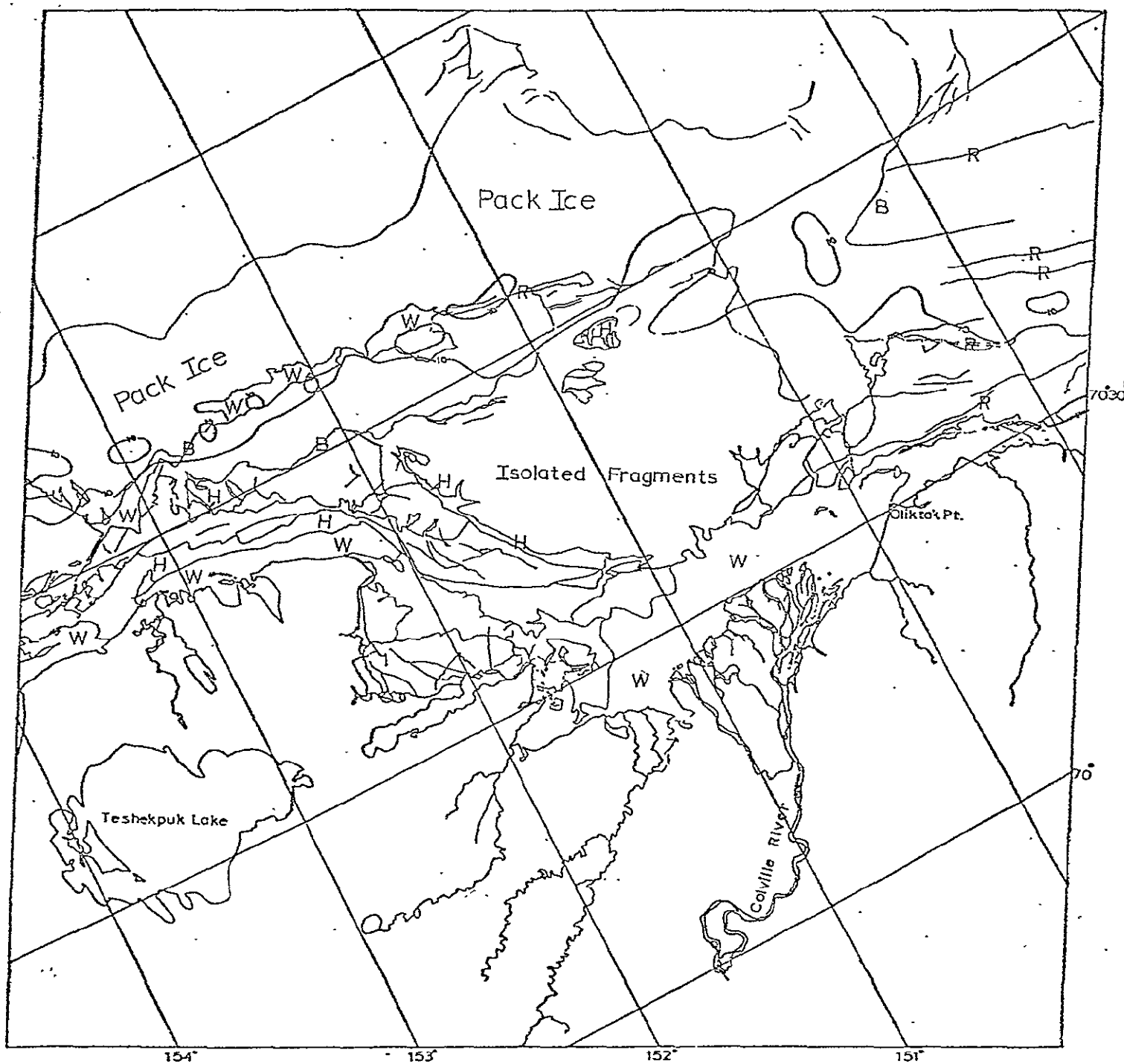


BEAUFORT SEA

Scene E-1345-21342

This scene shows the portion of Beaufort coast from east of Oliktok Point westward to Lonely for early summer (3 July) 1973. Because of the considerable overlap with scene E-1344-21283 obtained the previous day, this discussion will concentrate on that (western) portion not described for that image. Detailed analysis shows that during the 24-hour period between the two images, the pack ice has moved several kilometers westward.

On the western portion of this image the boundary between open water and ice presumably grounded is irregular although it generally follows the 10-fathom contour. The extensions of the shear ridges mapped just to the east have apparently continued westward. On the western side of the image can be seen a notable exception to the general rule of grounded ice following the 10-fathom contour: there is a large shoreward extension of open water. No shear ridges are evident in this area.

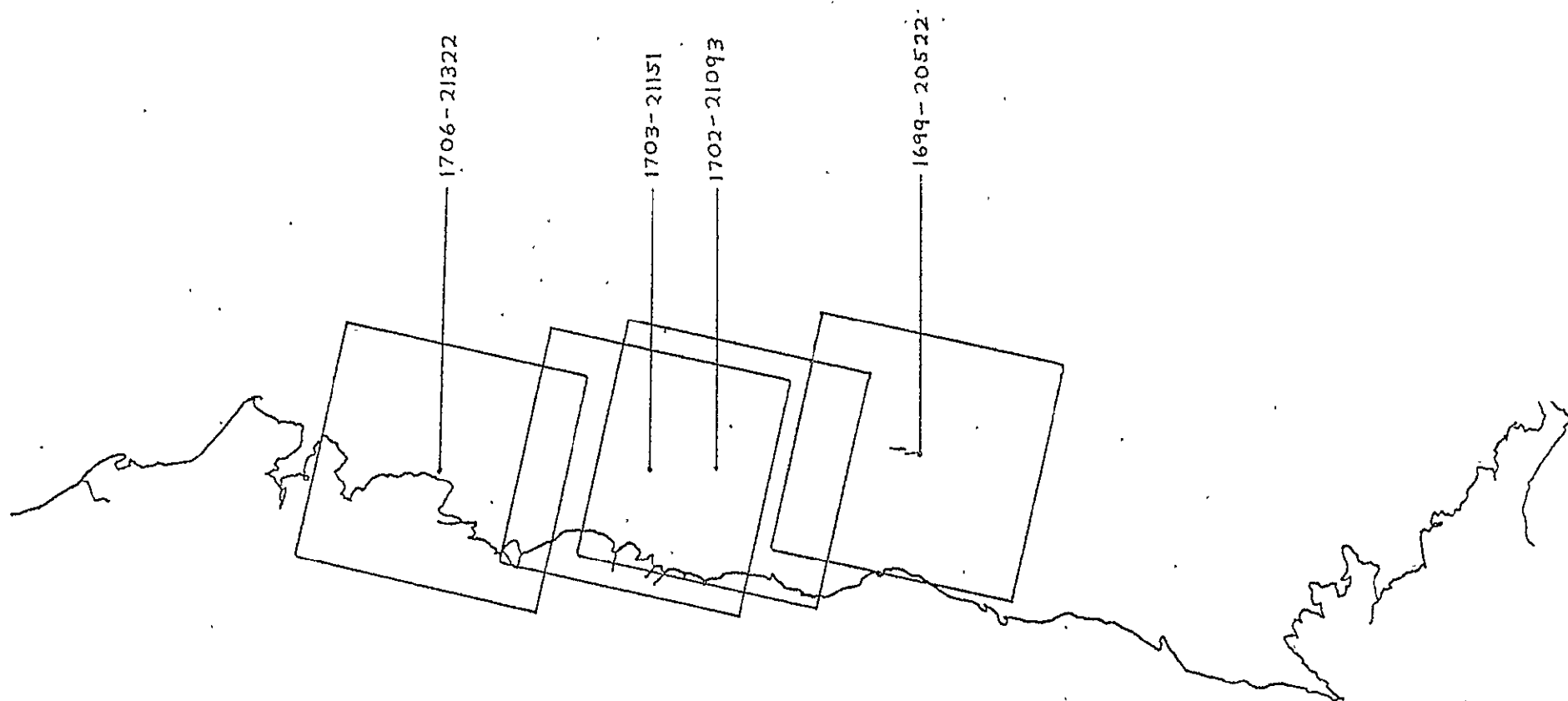


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-1345-21342-7  
3 JULY 1973

21



BEAUFORT SEA

13 JUNE - 30 JUNE 1974

Images: 1690-1707

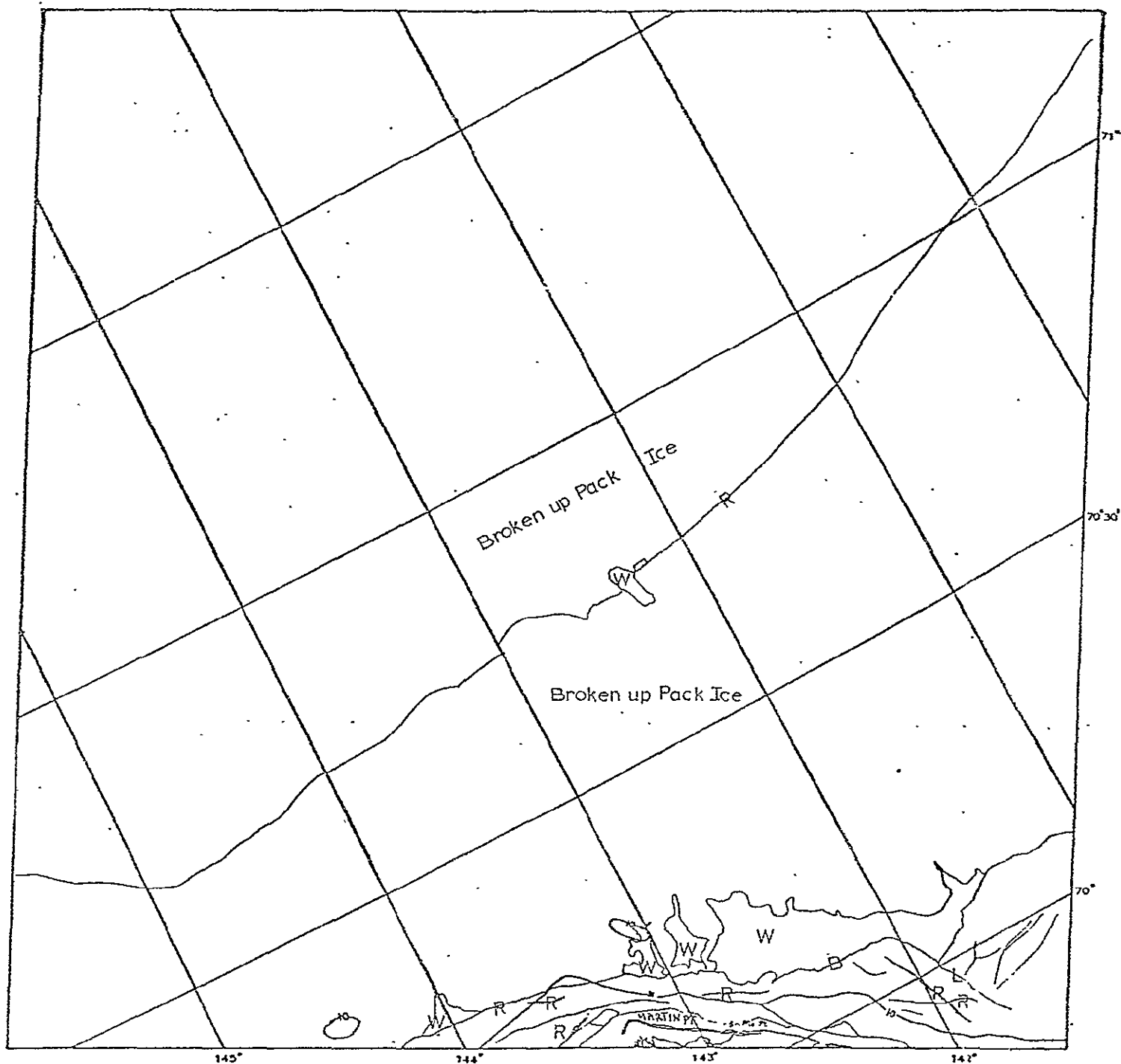
Scene E-1699-20522

This scene shows the portion of Beaufort Sea coast in the vicinity of Martin Point for late spring (22 June) 1974.

To the west of Martin Point it has been possible to identify a well-defined boundary between pack ice and stable ice. This boundary gives strong indications of being a shear ridge. To the east of Griffin Point the boundary between pack ice and stationary ice can not be identified. A boundary which is an extension of the shear ridge to the west has been mapped. However, this boundary achieves its distinction by being the boundary between shore-bound ice and open water. It is very likely that this boundary is not determined by grounded ice. \_\_\_\_\_

Martin Point is the most prominent feature on the eastern Beaufort coast and as a result one would anticipate that shear ridges might be constructed in its vicinity. Although one ridge coincides with the 10-fathom contour, the most prominent shear ridge is located well shoreward of the seaward bulge of this contour.

Well seaward the remains of a very large extended ridge system can be seen.



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-1699-20522-7  
 22 JUNE 1974

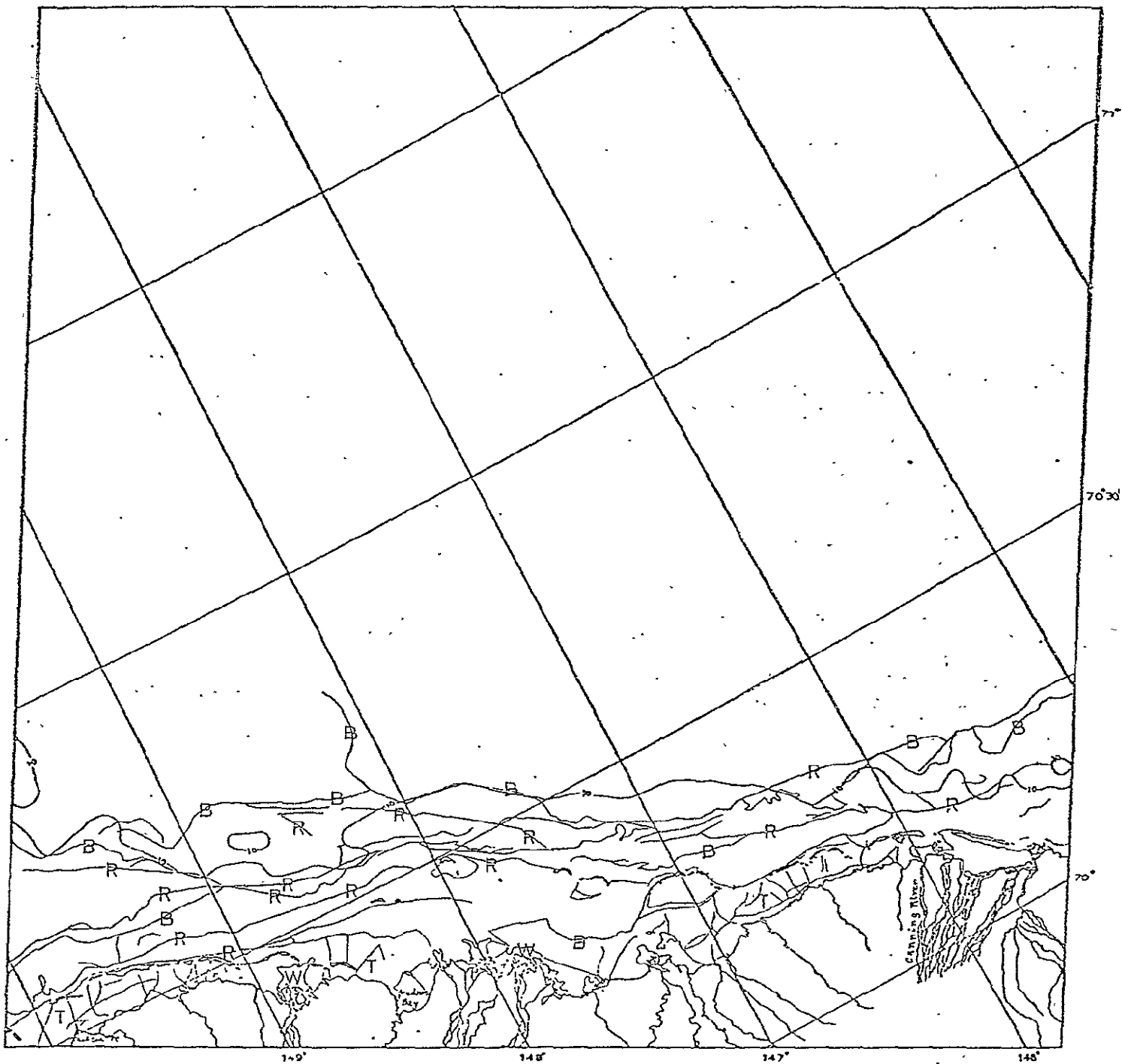
Scene E-1702-21093

This scene shows the portion of Beaufort Sea coast between Oliktok Point on the west and the mouth of the Canning River on the east for late spring (25 June) 1974. A boundary has been drawn roughly coinciding with the 10-fathom contour separating the broken-up ice pack from apparently more stable ice shoreward. Portions of this boundary are smooth and appear to have been determined by the locations of ridges while other portions of the boundary are irregular, suggesting this relationship does not hold in these locations.

Between this boundary and the shore, there are many long, curving features suggesting shear ridges. In some cases the ice piles associated with these features are sufficiently broad to have been resolved by the Landsat imaging system.

In the very near shore areas at the mouths of rivers, flooding has resulted in the creation of open water.





KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

BEAUFORT SEA

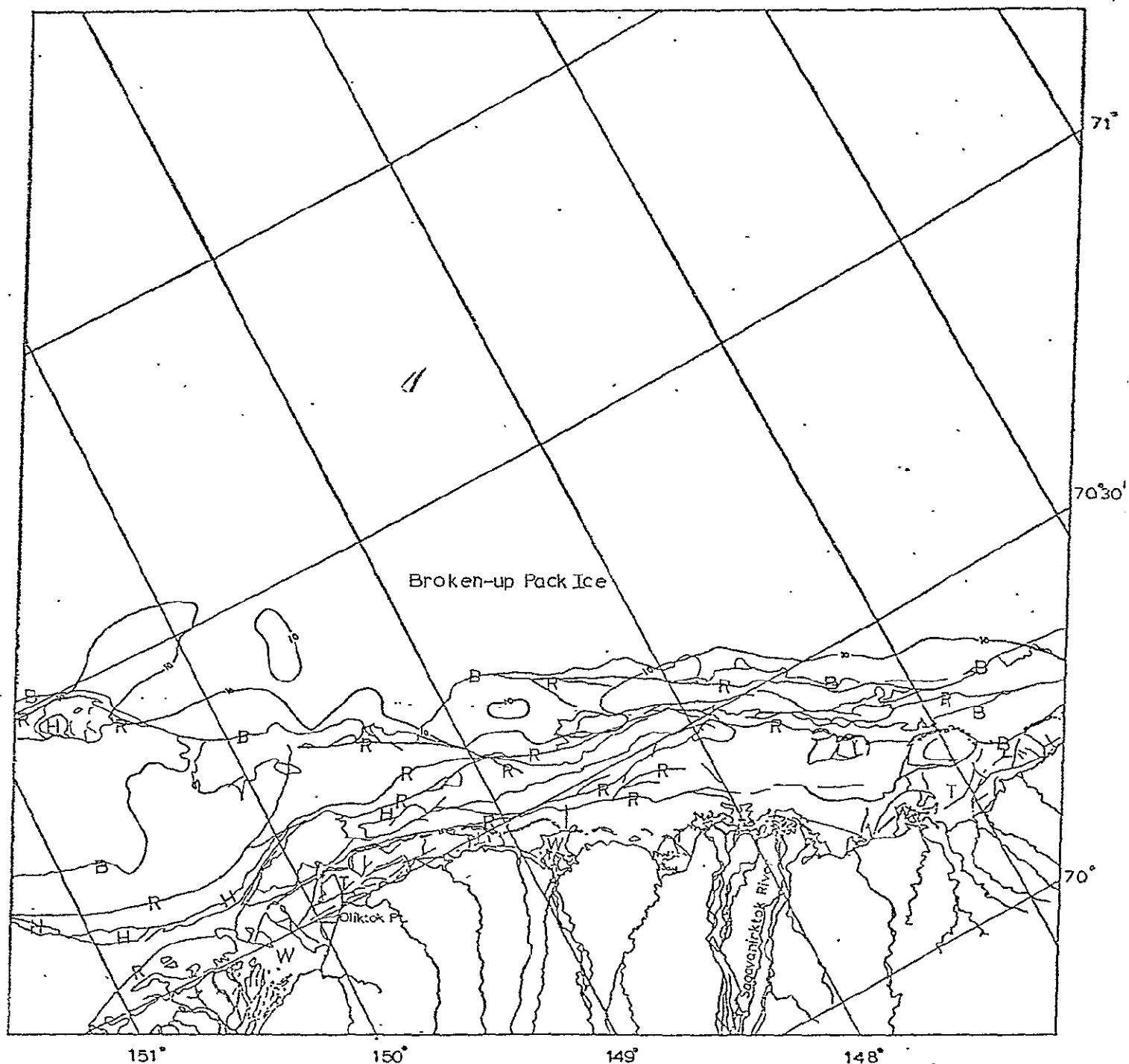
E-1702-21093-7  
 25 JUNE 1974

Scene E-1703-21151

This Landsat image shows the portion of the Beaufort Sea coast between the mouth of the Colville River on the west to beyond the Sagavanirktok River delta on the east. The image was obtained on 26 June 1974 and shows late spring ice conditions. A boundary has been drawn roughly coinciding with the 10-fathom contour separating the broken-up pack ice seaward from apparently more stable ice shoreward. Portions of this boundary are smooth and their positions appear to have been governed by locations of ridges while other portions of the boundary are irregular, suggesting that this is not the case in these locations.

Between the boundary noted above and the shore, there are many long, slightly curving features suggesting shear ridges. In some cases the ice piles associated with these features are sufficiently broad to have been resolved by the Landsat imaging system.

In the very near shore areas at the mouths of rivers, flooding has resulted in the creation of open water.



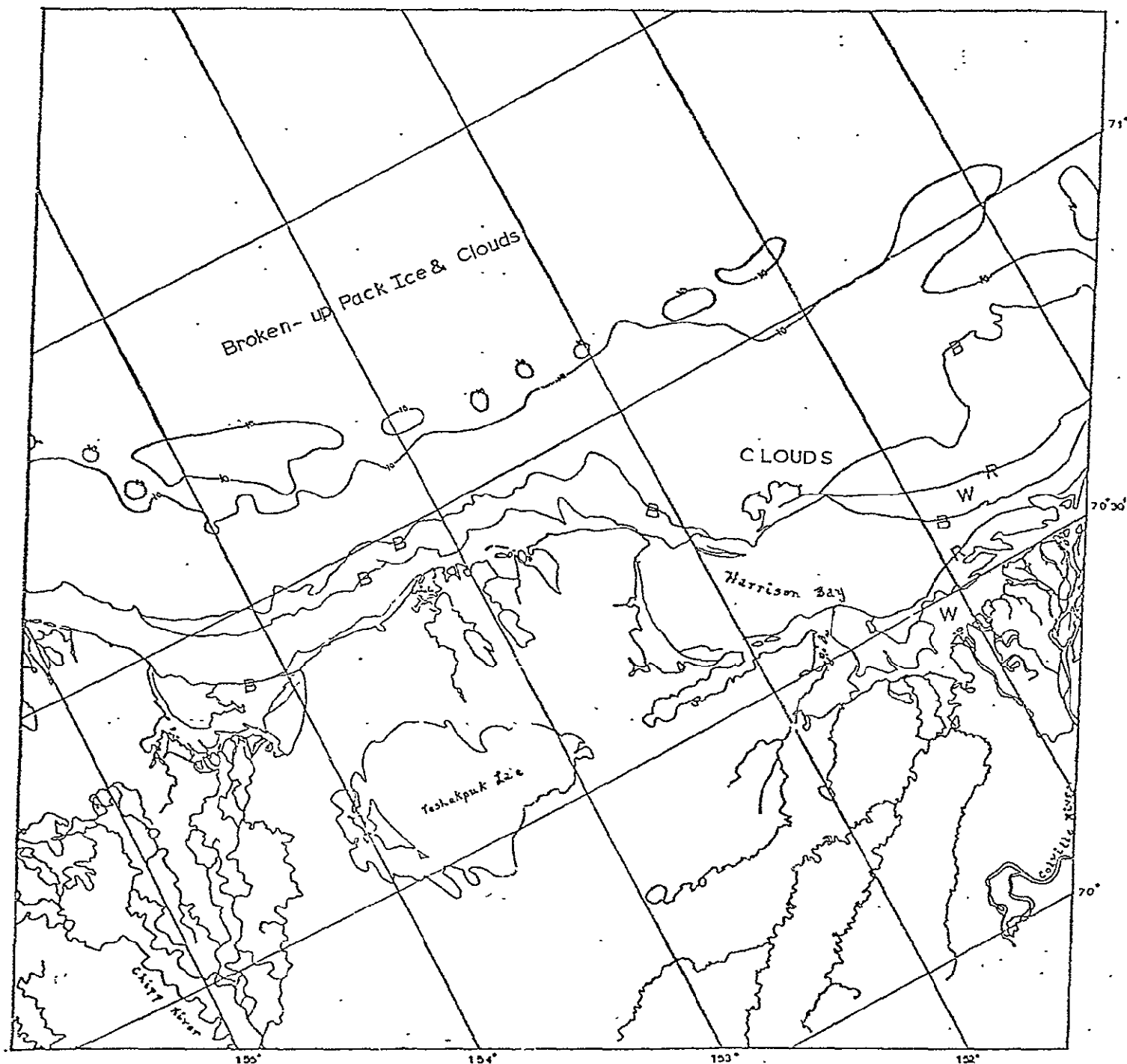
KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-1703-21151-7  
 26 June 1974

Scene E-1706-21322

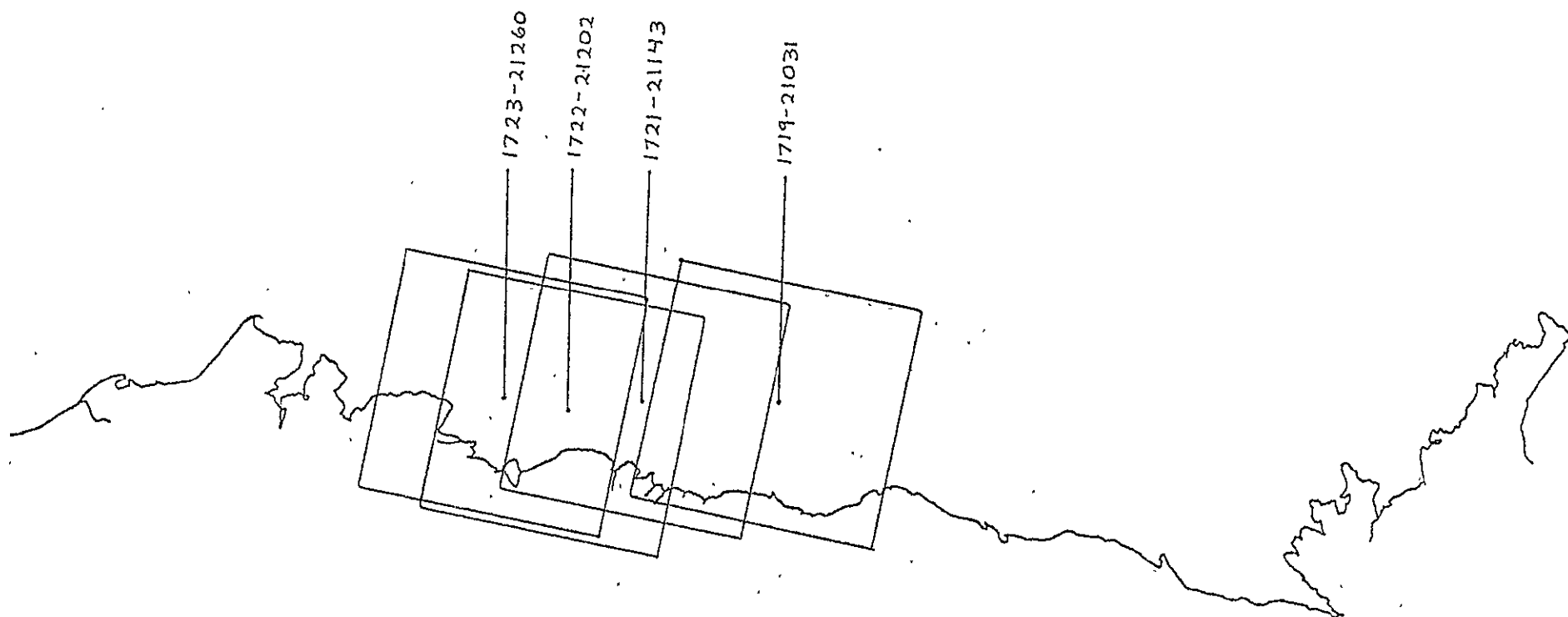
This scene shows the portion of Beaufort Sea coast from Smith Bay to the mouth of the Colville River for late spring (29 June) 1974. Clouds obscure most far offshore ice features except for the area in the vicinity of Smith Bay. In this area, the apparent boundary between stationary and pack ice is well-within the 10-fathom contour.



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-1706-21322-7  
29 JUNE 1974



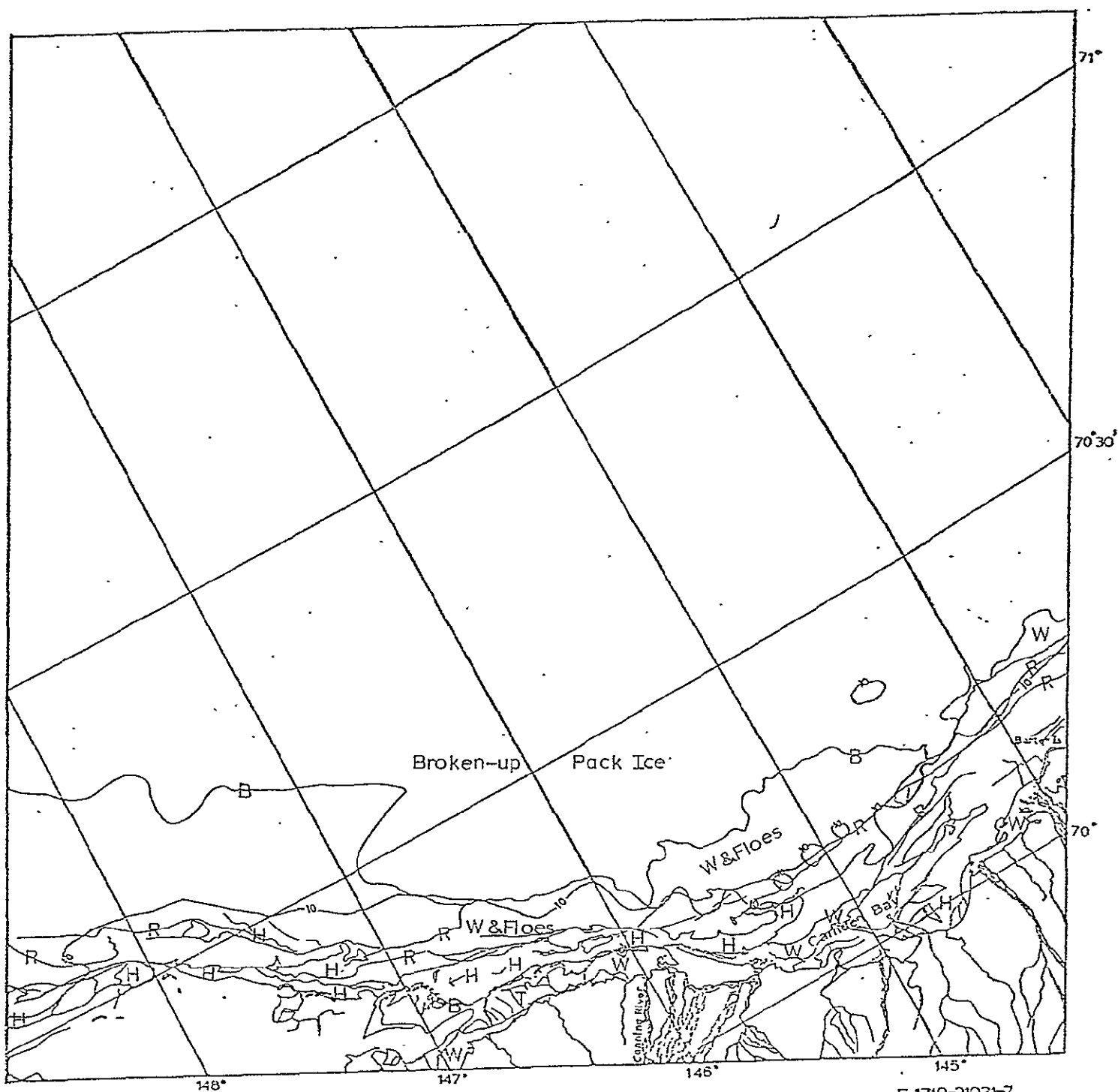
BEAUFORT SEA :

1 JULY - 18 JULY 1974

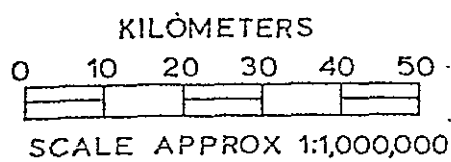
1708-1725

Scene E-1719-21031

This Landsat image shows the portion of Beaufort coast from Barter Island on the east to Cross Island on the west for early summer (12 July) 1974. In this area there is a fairly good distinction between free-floating pack ice and ice stationary with respect to the shore. Along most of this edge a ridge can be identified which roughly coincides with the 10-fathom contour. The most severe ridging seems to have occurred northeast of Barter Island and west of Cross Island.



E-1719-21031-7  
12 JULY 1974



BEAUFORT SEA

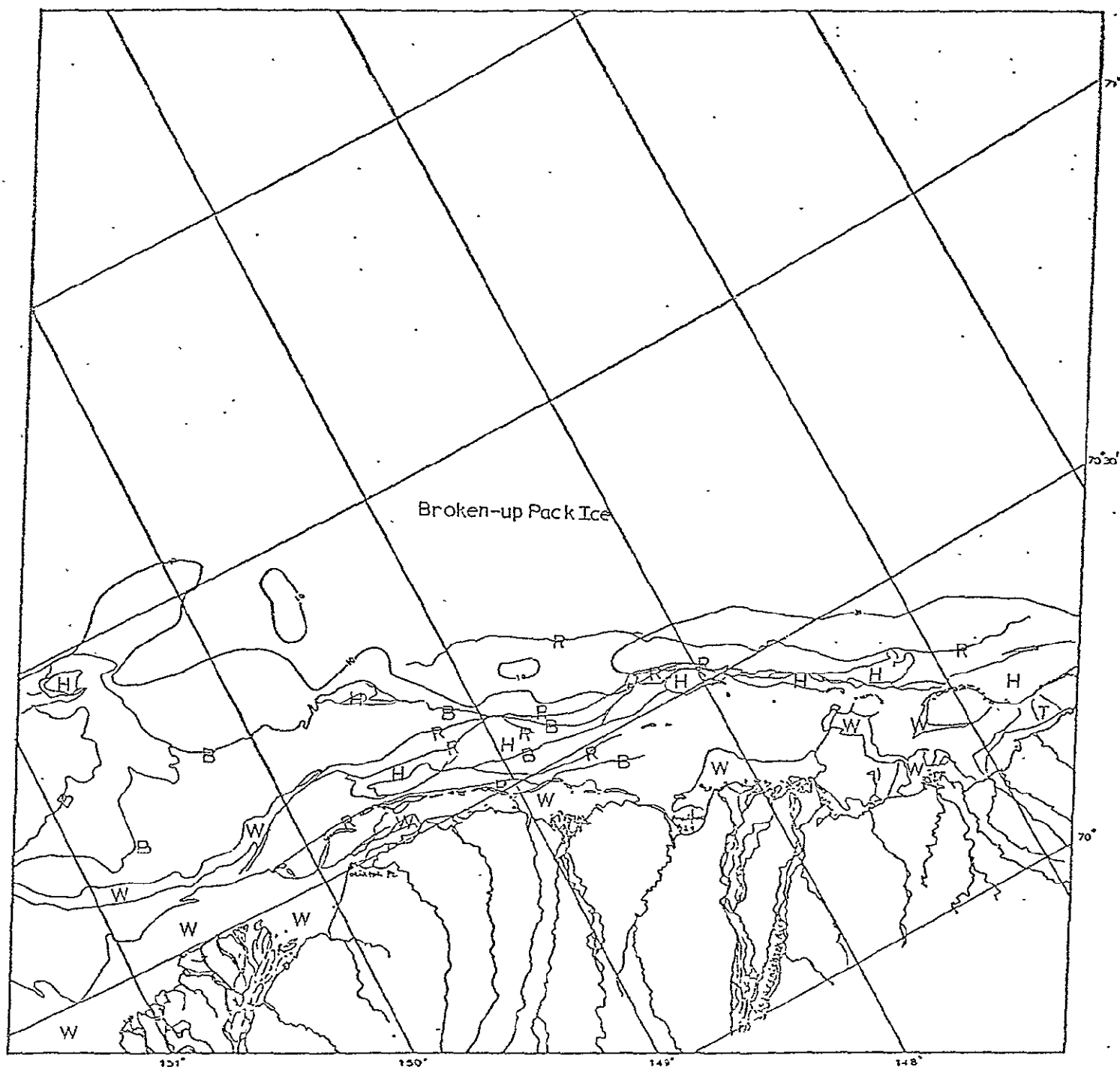


Scene E-1721-21143

This scene shows early summer (14 July) 1974 ice conditions for the Beaufort Sea coast between the mouth of the Colville River and Flaxman Island. It is not possible to distinguish everywhere between free-floating pack ice and ice grounded and stationary with respect to the shore. Generally speaking, east of  $149^{\circ}30'$  hummock fields or ridges can be identified which appear to serve as this boundary while west of this line only one hummock field can be seen which is apparently grounded. Between this hummock field and the one at  $149^{\circ}30'$  the boundary drawn is the dividing line between nearly melted ice and ice with a drained surface. No ridges can be identified along this boundary and the ice appears to consist of many individual pans of various sizes.

East of this line the boundary is characterized by many extensive ridge systems. A very large system of massive ridges can be seen just seaward of the hummock field mapped at  $148^{\circ}W$ ,  $70^{\circ}30'N$ , adjacent to Cross Island. Shoreward of these ridge systems there are a few other ridges, some hummock fields, and a considerable quantity of well-melted ice.

Several ice features in this scene were photographed during an aerial reconnaissance of the Beaufort Sea just a few days later than this image date. Comparison of these photographs with corresponding portions of the Landsat image will constitute a special report.



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

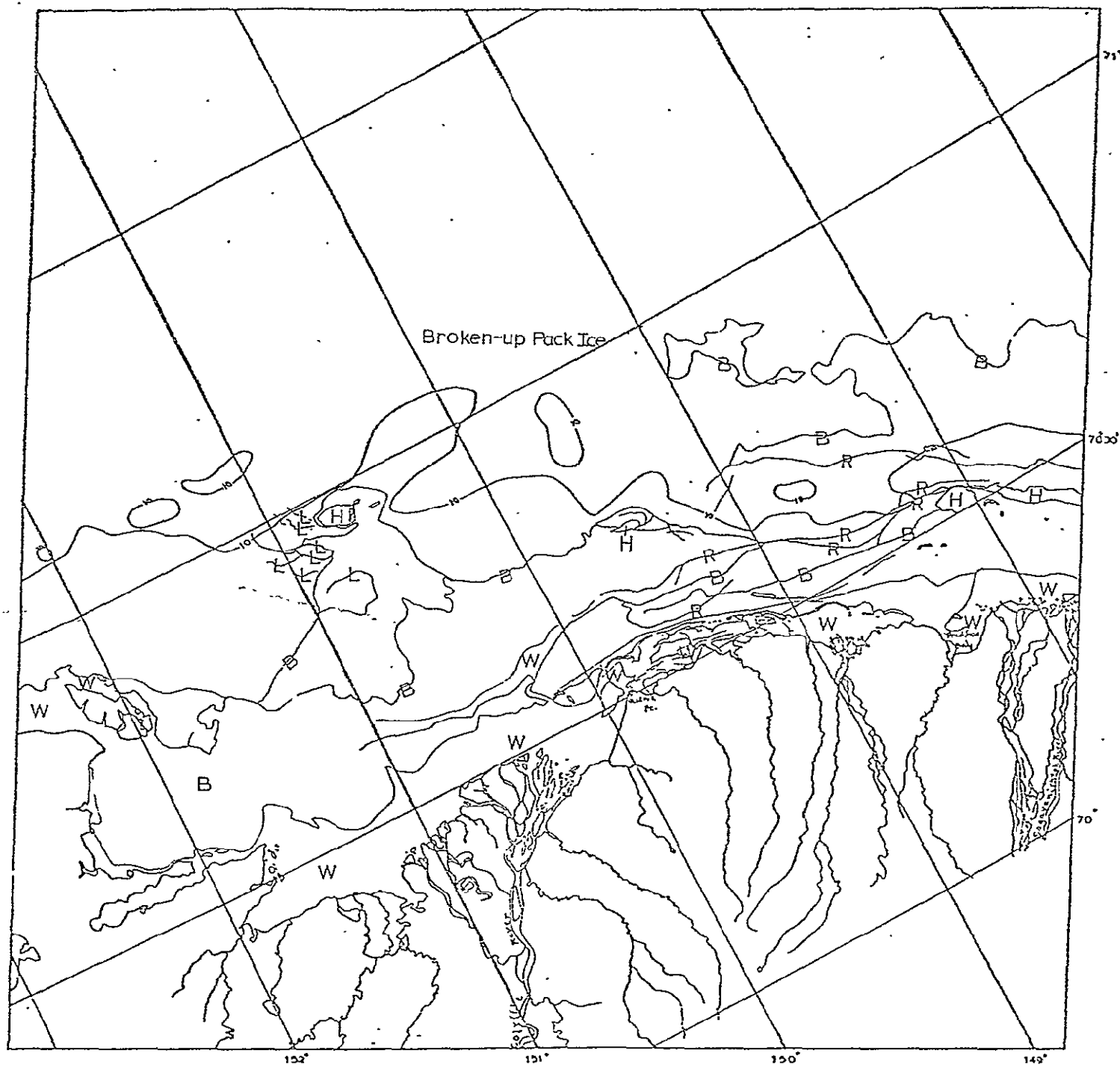
BEAUFORT SEA

E-1721-21143-7  
14 JULY 1974

#### Scene E-1722-21202

This Landsat scene shows early summer (15 July) 1974 ice conditions for the Beaufort Sea coast between Cape Halkett and the mouth of the Sagavanirktok River. It is not possible to distinguish everywhere between free-floating pack ice and ice grounded and therefore stationary. Generally, east of  $149^{\circ}30'$  hummock fields or ridges can be identified which appear to represent this boundary while west of this line only the hummock field located at  $150^{\circ}45'W$ ,  $70^{\circ}55'N$  appears to be grounded (note the leads formed in the pack ice in motion past this feature). Between these two hummock fields and on to the western side of the image, no ridge systems or hummock fields are mapped. However, on Scene E-1703-22151 this sort of feature was mapped in this area. Apparently these features were only poorly anchored (if at all) and have now been broken up and displaced.

Refer to Scene E-1721-21143 for a discussion of ice features on the eastern side of this image.



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

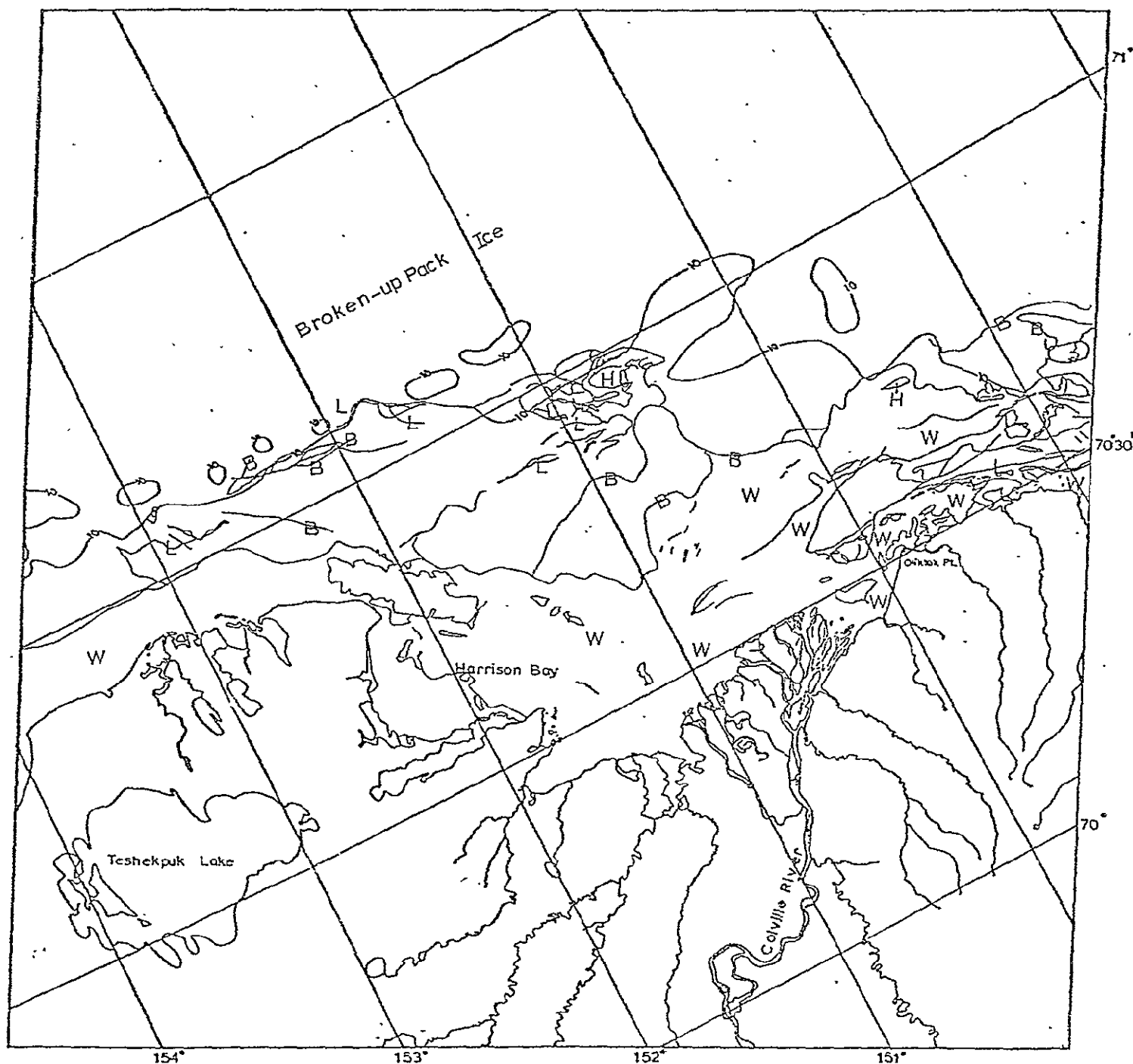
BEAUFORT SEA

E-1722-21202-7  
15 JULY 1974

Scene E-1723-21260

This Landsat image shows early summer (16 July) 1974 conditions between Smith Bay in the far west and the barrier islands east of Oliktok Point. Most of this scene has been described in the texts for scenes E-1722-21202 and E-1721-21143. This scene shows an area west of Cape Halkett not seen on the previous days' image but there is little change in the description for this new area from the description for the adjacent area to the east: it is difficult to identify features indicating grounded ice, except for one group of linear features along the 10-fathom line at 152°W.

One striking feature of this image is the degree of melting which has taken place since the previous days' image.

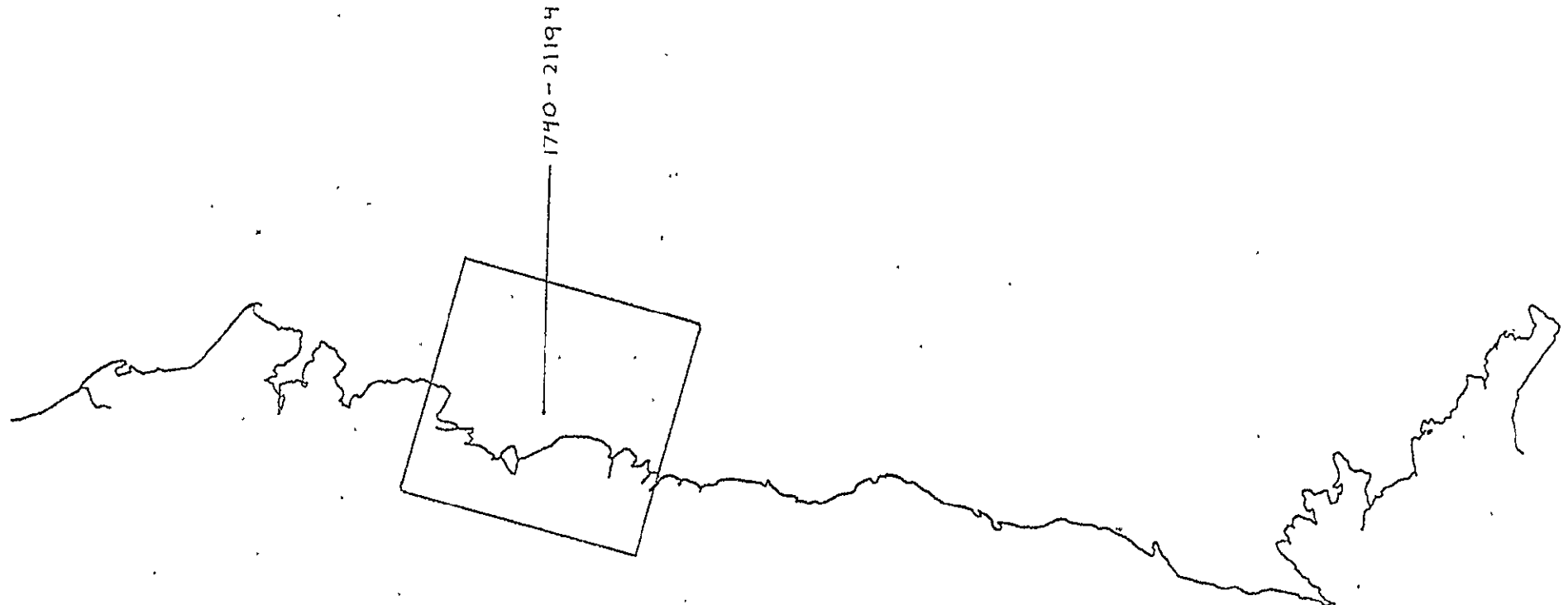


E-1723-21260-7  
16 JULY 1974

KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

BEAUFORT SEA

68

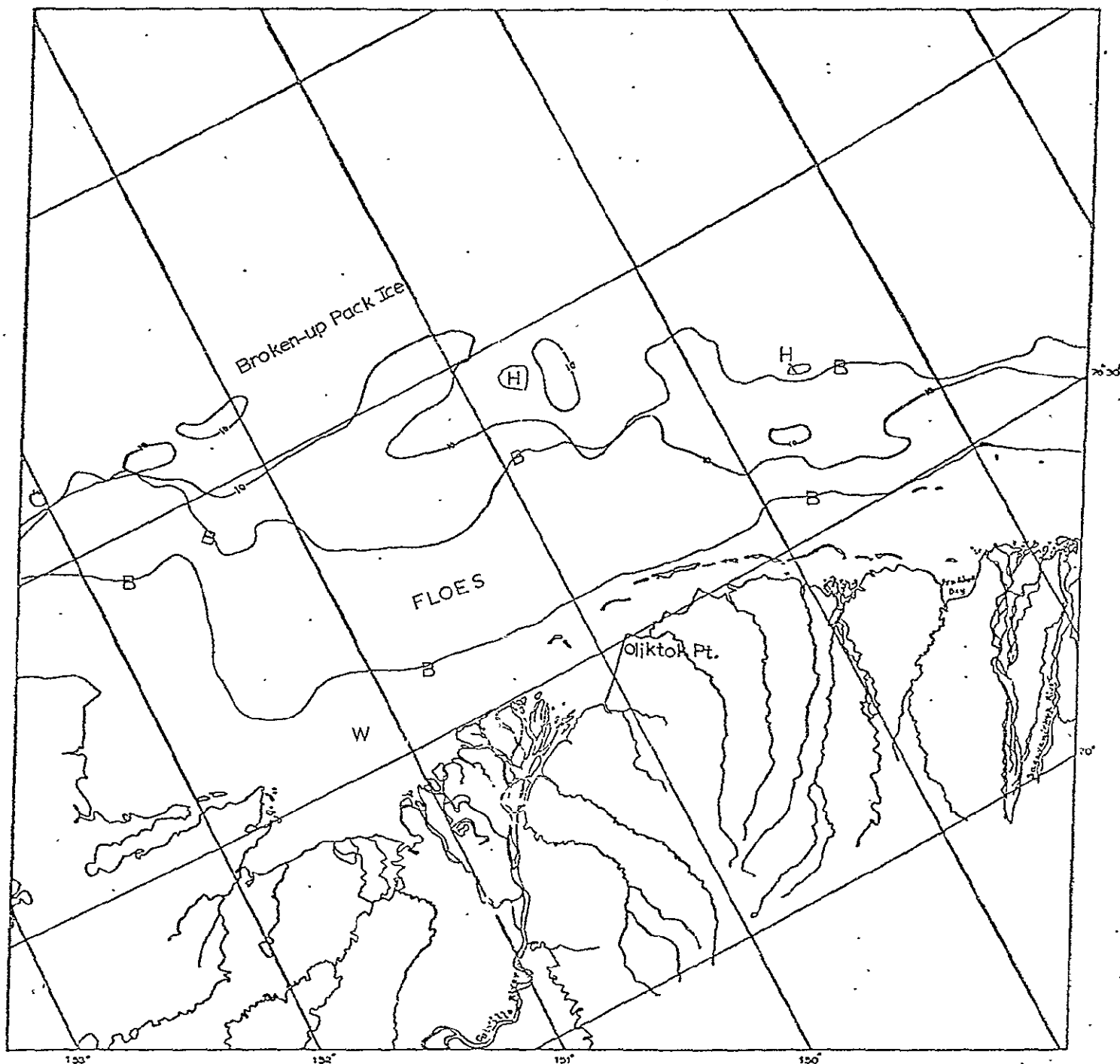


BEAUFORT SEA  
19 JULY - 5 AUGUST 1974  
Images: 1726-1743

Scene E-1740-21194

This scene shows the Beaufort coast from Cape Halkett to the mouth of the Sagavanirktok River for mid-summer (2 August) 1974. Three major zones have been delineated: "broken-up pack ice" consisting of closely packed individual pans, an area of "occasional floes" consisting of individual floes surrounded by water, and a region of "open water". At least two hummock fields remain grounded in outer Harrison Bay.



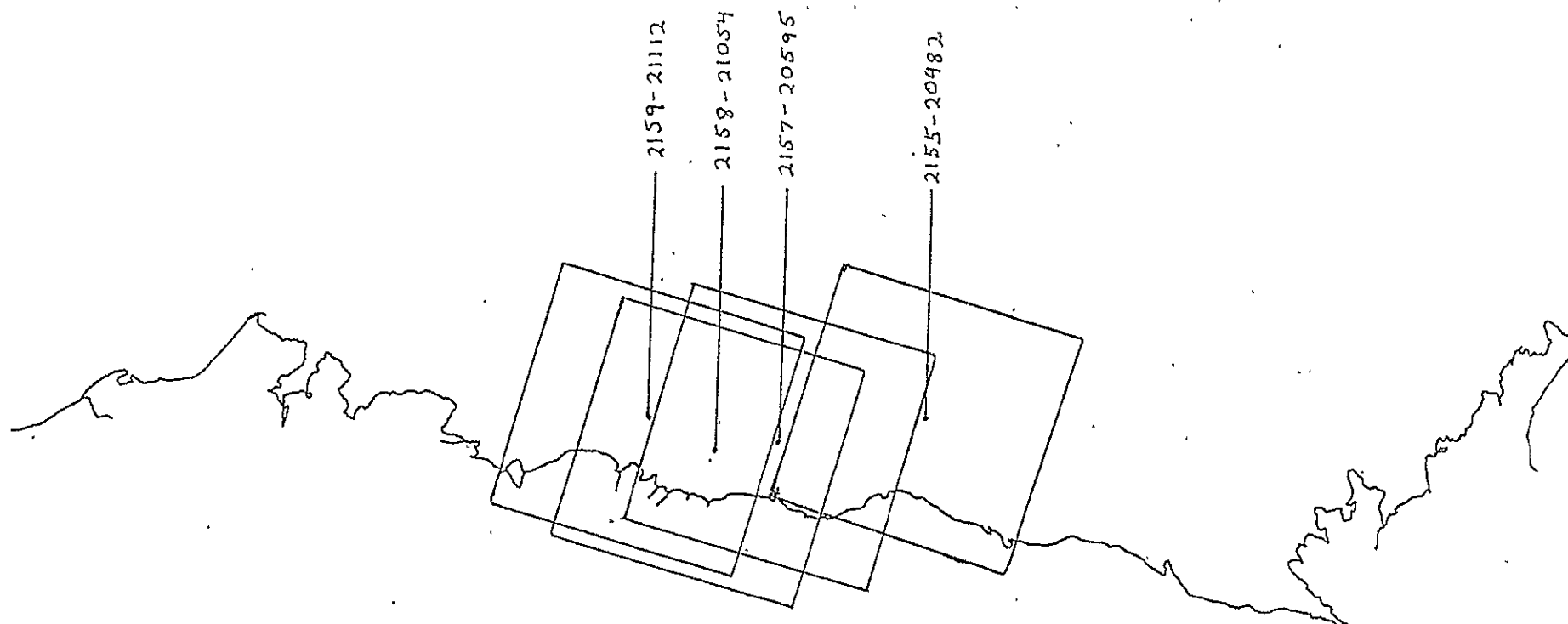


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-1740-21194-7  
2 AUGUST 1974

42

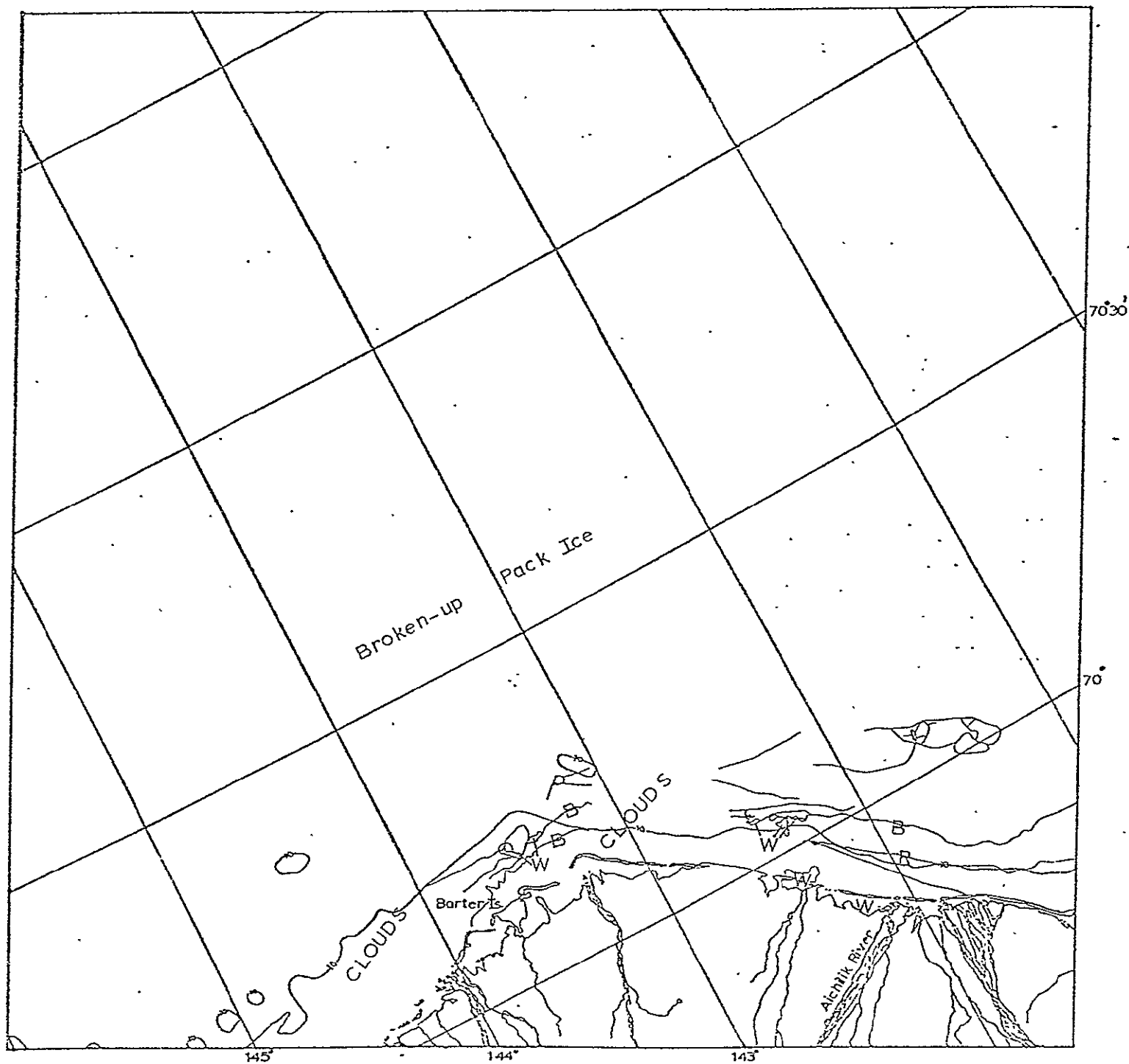


BEAUFORT SEA  
18 JUNE - 5 JULY 1975  
Images: 2147-2164

Scene E-2155-20482

This Landsat scene shows ice conditions in the Martin Point region of the Beaufort coast for late spring (26 June) 1975. This image contains considerable cloudiness and normally wouldn't be mapped except that in this instance the small amount of data to be gained was considered quite valuable.

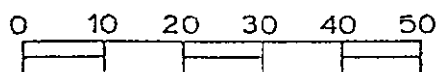
To the west of Martin Point is a lead well within the 10-fathom contour. This lead can also be seen in scene E-2157-20595 (next in this sequence). The significance of this lead is discussed in the annotation for that scene. The area of interest here is to the east of Martin Point where, although there is no evidence of massive ridging, the boundary of stationary ice is well beyond the 10-fathom contour.



E-2155-20482-7

26 JUNE 1975

KILOMETERS



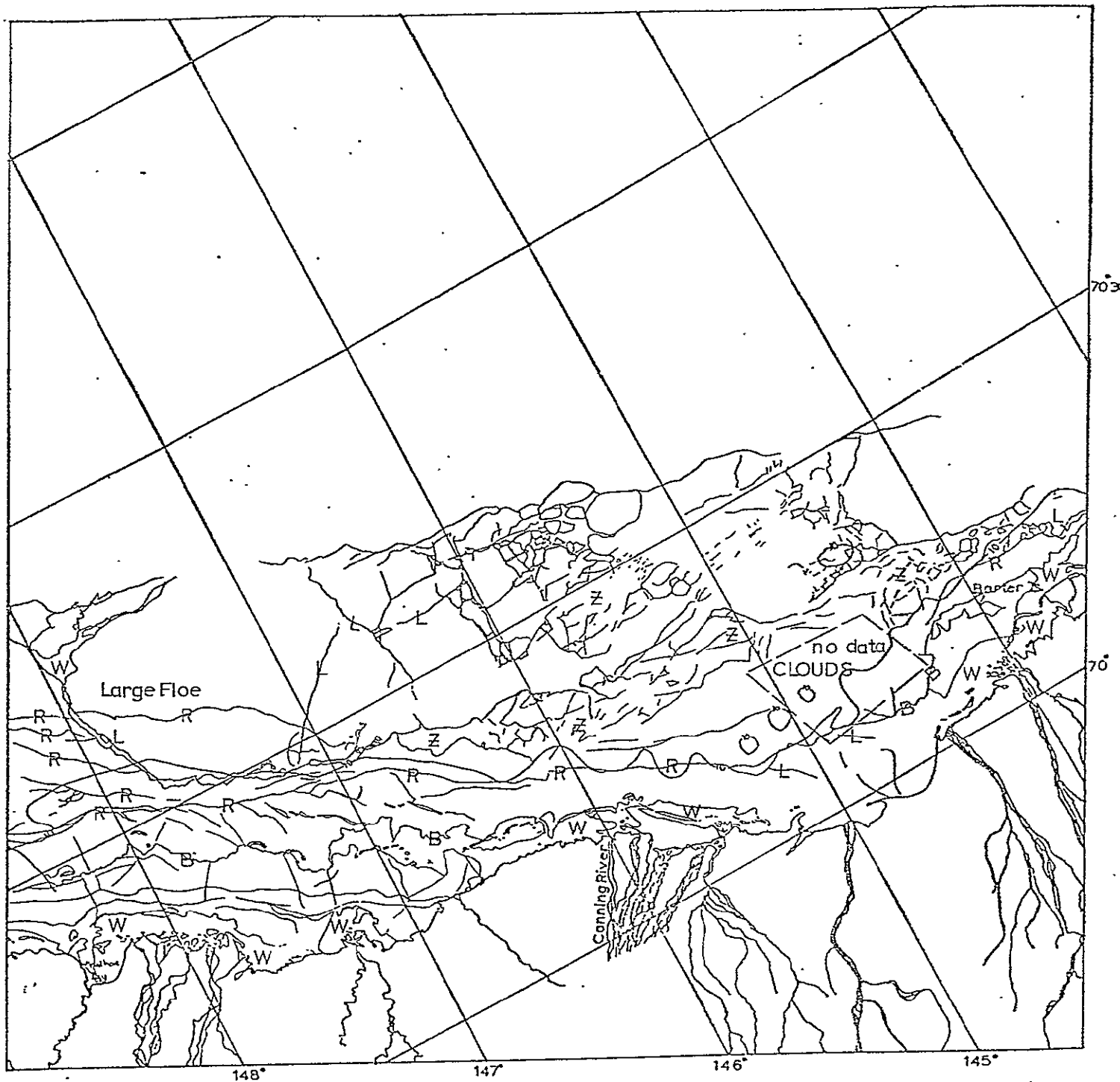
SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene E-2157-20595

This scene shows the portion of Beaufort coast between Barter Island and Prudhoe Bay for late spring (28 June) 1975. The west side of this image is overlapped by imagery obtained on succeeding days. Details of this area are discussed for that imagery. The area of interest provided by this image is from off the mouth of the Sagavanirktok to Barter Island. Over much of this distance there are ridges which appear to be grounded roughly following the 10-fathom contour. One small area of cloudiness obscures a very interesting portion of this coastal region: the somewhat sheltered Camden Bay. There is some evidence that the coastal ridge systems are not well-constructed in this area and at the time of this image are cut by fresh leads.

Note the large lead just off Martin Point at the extreme eastern side of this image. This lead is well within the 10-fathom contour. It would appear that the ice here is not nearly as stable as Harrison Bay ice which will be seen on later images in this Landsat cycle.



E-2157-20595-7  
28 JUNE 1975

KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

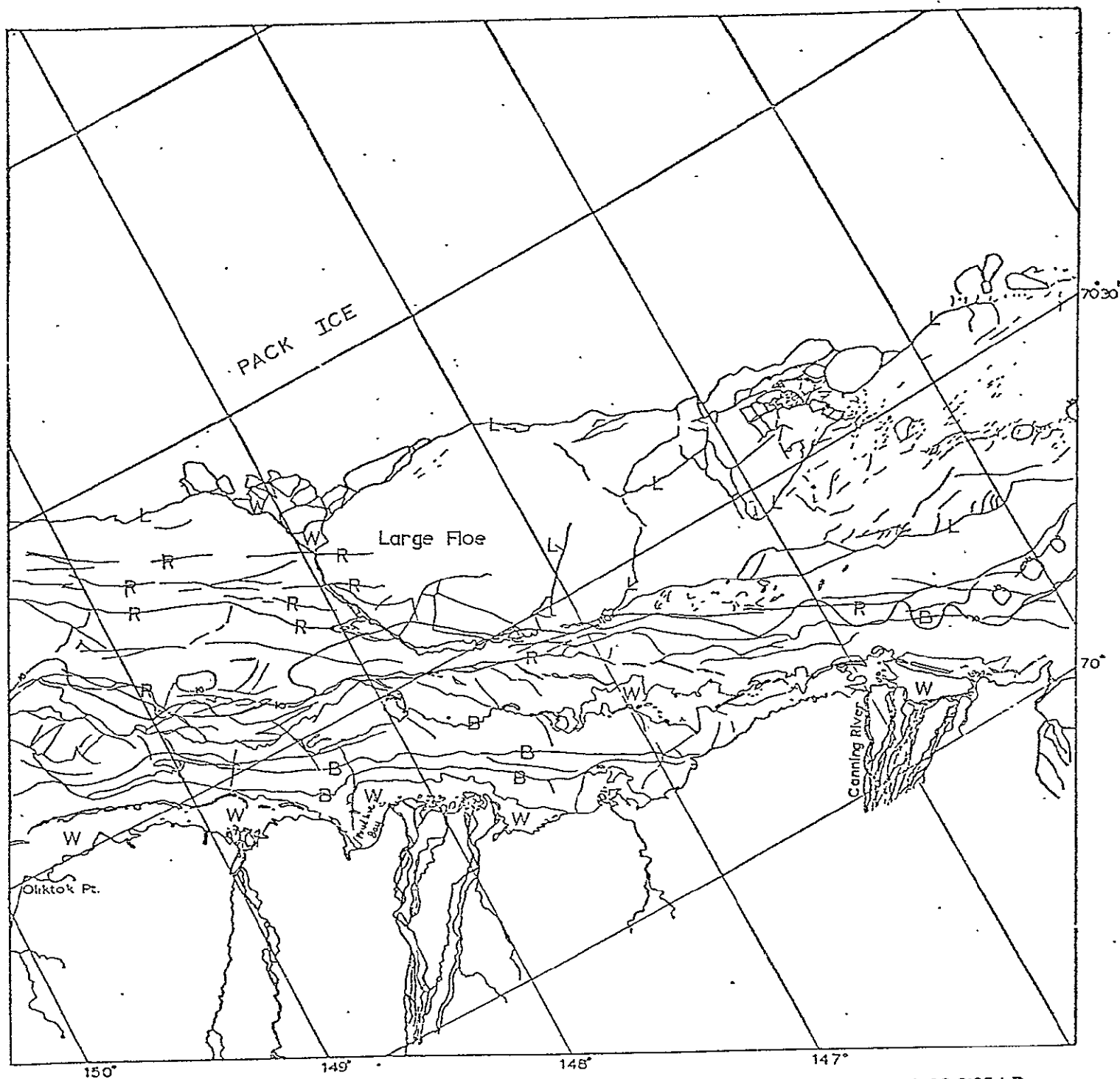
BEAUFORT SEA

Scene E-2158-21 054

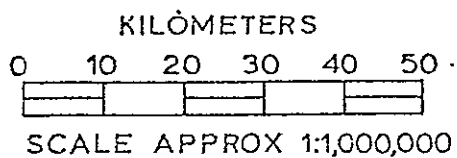
This scene shows the portion of Beaufort coast between Oliktok Point and the mouth of the Canning River for late spring (29 June) 1975.

An unusual amount of ice remains contiguous for this time of year. Perhaps part of the reason is the many well-developed ridge systems running parallel to the coast. Very recently a large piece of this contiguous ice sheet has broken off and moved slightly eastward, the motion in that direction being permitted by the shattered pack ice to the east.

From Prudhoe Bay eastward, the boundary of stationary ice appears to coincide with the 10-fathom contour. To the west of Prudhoe Bay contiguous ice extends considerably seaward of the line.



E-2158-21054-7  
29 JUNE 1975



BEAUFORT SEA

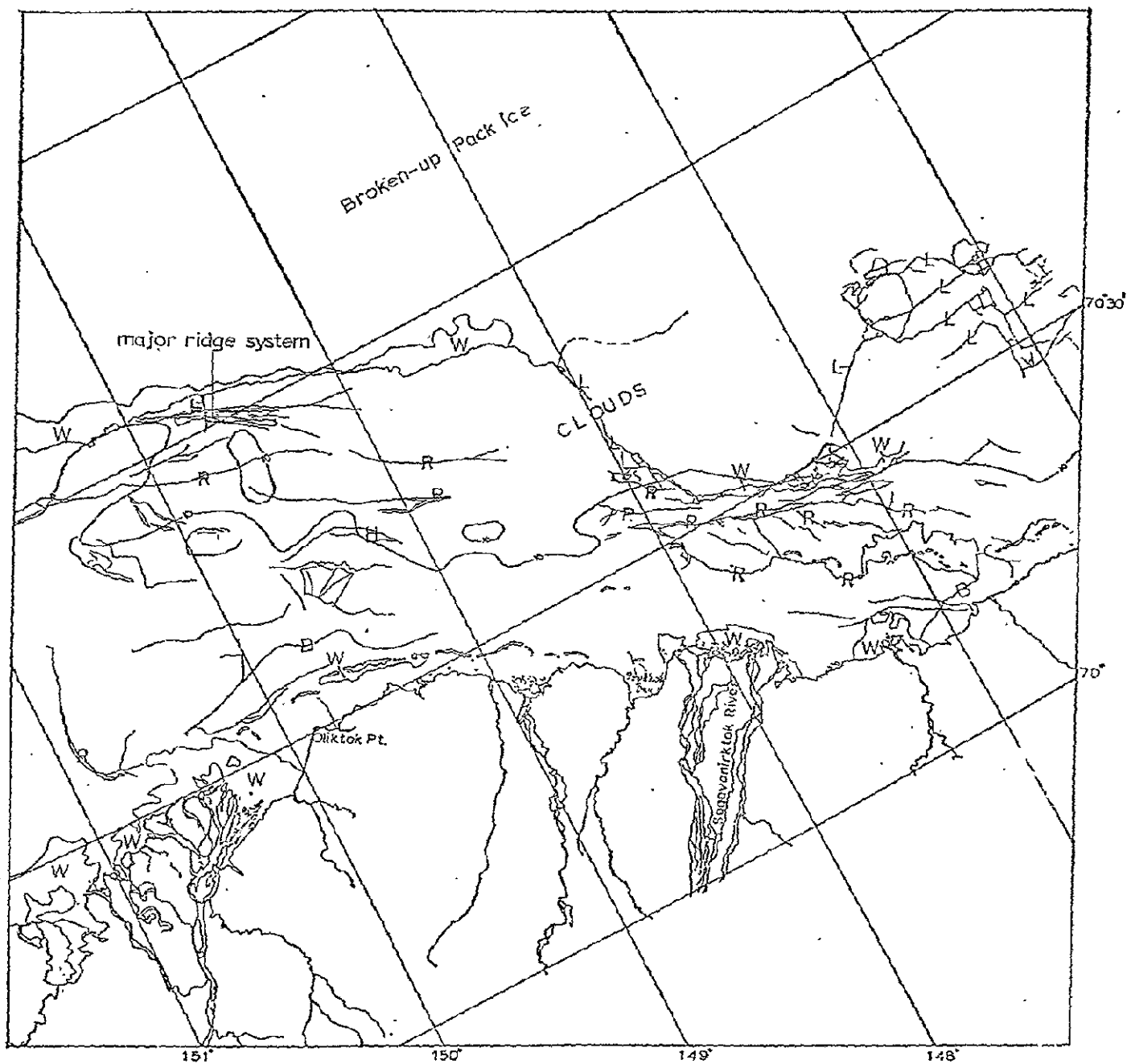


Scene E-2159-21112

This scene shows the portion of Beaufort coast from the mouth of the Colville River eastward to Maguire Island for late spring (30 June) 1975. There are several interesting features mapped from this image: the chief of which is the "major ridge system" indicated on the western side of the map. This ridge system will be seen to survive the 1975 melt season and remain in place through the winter of 1975-1976. It was not entirely stable however, and as shown here, was cut by a major lead.

Clouds obscure details in the central portion of the image making features there difficult to map. However, the boundary between pack ice and stationary ice can be mapped. It is interesting to note that this boundary is located at this time well beyond the 10-fathom contour to the west of Cross Island.

There are several areas of open water just offshore from the mouths of major rivers.



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-2159-21112-7  
 30 JUNE 1975

ICE HAZARDS TO OFFSHORE OIL OPERATIONS  
IN ARCTIC ALASKAN WATERS\*

W. J. Stringer  
W. M. Sackinger

Geophysical Institute  
University of Alaska  
Fairbanks, Alaska 99701

I. Introduction

Sea ice presents a hazard to offshore drilling structures and associated support activities which can exceed the normal hazards of winds and waves by a considerable margin (Hudson, 1973). Fortunately, along much of the Arctic coastline the ice is grounded during the last half of the winter, exerting only nominal internal stresses (Nelson et al., 1976). However, under breakup circumstances, this nominally shorefast ice can acquire velocities of 2 m/sec or more (Sackinger et al., 1974), and under such circumstances is likely to produce stresses which may be as great as those experienced in the moving ice pack.

Locations with more extreme ice hazards are found beyond the boundary of the shorefast ice, on the prevailing sides of coasts and islands, and in relatively deep ( $\geq 20$  m) unsheltered water where the ice moves virtually continuously. The proposed Outer Continental Shelf lease sale areas in the Bering, Chukchi and part of the Beaufort Sea are largely in this latter category. It is obviously important to document the regions of relatively safe, shorefast ice, and a study of LANDSAT (Land Imaging Satellite) imagery is currently in progress to do so. The dynamics of the shorefast breakup events are also being studied using time-lapse photography of the screen of the University of Alaska sea ice radar at Barrow, Alaska.

\* Presented at 31st Annual Petroleum Mechanical Engineering Conference, Mexico City, September 21, 1976.

In this paper, we describe the annual cycle of Beaufort Sea near shore ice events and discuss the possible hazards related to these various ice conditions.

## II. Beaufort Sea Near Shore Ice Conditions

Usually the Beaufort Sea coast is ice-free during August and September. Ice formation begins in October and generally does not form a dependably stable surface until late December or early January. The stable surface, when formed, is usually referred to as "shorefast ice". Although several slightly differing definitions of "shorefast ice" are in common usage, the term generally refers to ice stationary with respect to the shore and bounded by grounded ice features [shear and pressure ridges, floebergs, stamukhi, etc., (see Kovacs and Mellor, 1974)].

The processes at work during the formation of shorefast ice are not well-documented, largely because they have not been at the focus of attention. These processes occur during the dark winter months, when satellites with high resolution visible spectrum sensors are not operative.

However, it is known that the formation of the fast ice usually takes place in stages, often punctuated with episodes of wind-driven ice being piled and compacted into successive bands parallel to the coast. Many of these features are grounded and serve to anchor the surrounding ice in place. Along the Alaskan Beaufort coast this anchoring effect seems to function to a water depth of approximately 20 m. Hence, the 20 m bathymetric contour is usually taken to be the nominal seaward limit of Beaufort Sea shorefast ice.

Dynamic ice events can and do occur within the "shorefast" zone before the ice becomes sufficiently anchored to be reliably stable. Although these events are presently unobservable by means of high resolution imaging satellites, other techniques exist, which although limited in comprehensive geographic coverage, give detailed information. One of these techniques is imaging radar.

Radar has proven to be a valuable tool for the study of the dynamics of shorefast ice during formation and breakup. The University of Alaska sea ice radar facility was established at Point Barrow in March 1973, supported jointly by the Alaska Oil and Gas Association and the Alaska Sea Grant Program. Using time-lapse photography of a conventional cathode ray tube display, it has recorded the motion of sea ice for over three years.

A particularly severe and unusual breakup event has been analyzed by Shapiro (1975). Until 26 December 1973, the ice was landfast out to beyond the 20 meter water depth contour. An offshore wind in the range 13-24 km/hr prevailed for 15 hours when, at 0545 U.T. on 26 December, the ice broke free and drifted away from the coast at 0.7 km/hr. The windspeed reached 30 km/hr at that time. The time-lapse film shows subsequent ice motion parallel to the shoreline at 3.7 km/hr.

Subsequently, on 31 December the wind velocity increased to 90 km/hr (with gusts to approximately 150 km/hr) parallel to the shoreline. The ice drift velocity increased to 8.3 km/hr, parallel to the shore, and impact of this drifting ice was sufficient to drive out other ice floes which had grounded on shoals earlier. This sequence represents the most severe condition of drifting ice in the shorefast zone which has yet been analyzed.

In order to illustrate the optically observable portion of the annual cycle of near shore ice dynamics, a sequence of LANDSAT scenes showing the vicinity of Prudhoe Bay, Alaska, 1974 will be used. Near shore ice forms during the dark months when there is insufficient light for LANDSAT imagery to be obtained. Typically, the earliest LANDSAT scenes of the Prudhoe Bay area are available in late February or early March. Figure 1, obtained on March 10, shows the already formed "shore-fast" ice and evidence of shearing motions in the pack ice beyond. Because no imagery is available from the period of fast ice formation, knowledge of that period must be gleaned from this earliest scene, and as it will turn out, late season imagery.

Close examination of this LANDSAT scene shows several discontinuous bands of similarly textured or shaded ice more or less parallel to the coast. These bands represent various stages in the "freeze-up" of the near shore ice. The stages represented include freezing in place, compaction, piling and rafting of ice frozen in place, and piling and rafting of newly-formed or multi-year pack ice driven into the near shore area. The boundaries of each of these bands were each once the seaward edge of the ice, fixed with respect to the shore, and could have been the site of formation of shear or pressure ridges for some period of time.

Each boundary is located in successively deeper water and hence could be subject to more severe ridging conditions. Just seaward of the most pronounced bands a series of large, massive shear ridges can be identified on the imagery. These too, formed during "freeze-up".

However, as will be seen, these ridges are well shoreward of the location of shearing conditions by the date of this image.

The most visible indications of shear are the newly-formed and refrozen lead systems running somewhat parallel to the coast. Examining first the older, now refrozen, lead it can be seen that its formation involved displacement of the pack ice to the east a distance of several kilometers. Further, the pattern exhibited by the other refrozen leads is that of stress relief, showing that the release was not limited to the slippage along this lead. The appearance of the outermost of the refrozen leads indicates that after their formation, there may have been some westward slippage of the polar ice beyond this lead, thereby opening it up.

Now, on March 10, after this lead system has frozen over, a new lead system is forming. Examination of this new lead system indicates westward displacement along two lines: The outermost new lead coincides with the outermost lead of the former lead system and the inner lead runs for some distance within the boundaries of the refrozen leads, but then strikes off slightly seaward of the former lead.

This image then illustrates the concepts of "shorefast" ice and the active "shear zone".

The next LANDSAT image available for this area was obtained on March 28 (Figure 2) during the succeeding LANDSAT cycle. Where formerly the ice exhibited a displacement gradient with westward displacements increasing with distance from shore, it appears that sometime during this 18 day interval, the ice seaward of the most shoreward of the old lead system has moved several kilometers westward as a block, largely

obliterating the old refrozen lead. Presumably during this time pressure and shear ridges of considerable magnitude were created. Examination of imagery from the summer melt season will show that the ridges formed during this event persisted into that period.

The next LANDSAT data would have been obtained in mid-April, but this image is not available - probably due to excessive cloud cover. The May 3 image (Figure 3), obtained on the second LANDSAT cycle after the late March scene, shows that little, if any, change has taken place other than perhaps further compression of the refrozen leads. Hence, during this period of over one month, Beaufort Sea ice off Prudhoe Bay was not subject to conspicuous shear or breakage for at least 50 miles offshore. Apparently this is a somewhat common occurrence, having been observed the previous year also (see Stringer, 1974).

On the west side of this image is an oblong ice feature which, while extant on the earlier images, can be examined for detail for the first time this season on the LANDSAT image under discussion. This grounded hummock field appears to be a recurring feature and has been reported earlier (Stringer, 1974), based on 1973 observations. An aerial reconnaissance of this feature was performed in July 1974, which confirmed the nature of its structure. There is reason to believe that this feature and the large grounded feature west of Barrow (Stringer and Barrett, 1975) are the result of similar processes and represent essentially the same general type of ice feature. Note that lead systems are strongly deflected around this feature, indicating the major role played by its presence. On subsequent scenes it will be seen that the boundary of shorefast ice was seaward of this feature.



The next available LANDSAT image was obtained on May 21 (Figure 4). Here, the ice exhibits a marked change over the previous image. Whereas before this date the polar ice off Prudhoe Bay formed mainly a sheet continuous with the shorefast ice, now the polar ice is breaking up. This general behavior has been observed on imagery from other years at this date. However, it may be unusual for the pack ice to be broken up with such large voids between individual pans. Obviously, at this time the "shear zone" begins at the boundary of the ice continuous with the shore and the open water. On the west side of the image, the shear boundary nearly coincides with the boundary defined by much earlier ice activity but it is still actually somewhat seaward of this location. The grounded hummock field mentioned earlier is located at this point and it is worthwhile to note that this feature remained within the shear boundary. Our contention is that this feature was a factor in determining the shear boundary.

The shear boundary runs nearly eastward across the image, increasing its distance from shore and the edge of the shorefast ice toward the east. It is not uncommon for the shear boundary to coincide with the edge of shorefast ice at this time, however (see Stringer, 1974).

The next LANDSAT imagery of Beaufort Sea ice off Prudhoe Bay is available for June 25 and 26 (Figures 5 and 6). By this time, the Beaufort Sea pack ice is well broken up and moving. Examination of the LANDSAT images for these dates shows that there is a definite boundary between moving and non-moving ice. Further, this boundary coincides with the shear and pressure ridges observed under construction in late March. The late June images are especially useful for examination of

the make-up of the ice within the boundary mentioned. Many authors consider this ice "shorefast ice" but this definition is not held universally. Melting conditions have removed most of the snow cover from the ice, showing for the first time the detailed structure of the ice which was obscured on previous imagery. Here, the successive bands of ice within the shorefast zone can be examined for clues about their origin and alterations. It can be seen that some bands appear to consist of uniform sheets of ice which probably formed in situ, while others consist of compacted blocks of ice which were formed elsewhere and driven into their present location. Hence, the "freeze-up" of the shorefast zone was a dynamic event bringing highly variable ice conditions. We have seen that radar observations of shorefast ice formation at Barrow generally corroborate this behavior.

By July 14, when the next LANDSAT image is available (Figure 7), considerable deterioration of the shorefast ice has taken place. Near shore - particularly near river mouths - it has melted completely, while seaward particular pans and areas of pans have melted. Hummock field, shear and pressure ridges become more distinct due to their persistence.

The last LANDSAT image for the Prudhoe Bay area in this year was obtained on September 6 (Figure 8). It shows the near shore areas free of ice and the polar ice pack far beyond. Between the coast and the pack ice are several groups of floes which appear to be stranded at locations far offshore. Evidence supporting the contention that these groups of floes are stranded can be found in that other floes are passing around them toward the west exhibiting typical slip-stream patterns. This is not an uncommon occurrence (Reimnitz, 1976) and results when a

few pieces of ice of deep draft become grounded (or remain from the previous ice season). Currents and winds cause other ice floes to pile up against them. Brooks (1974) studied one occurrence of this phenomena and remarked on the relatively small number of grounded obstructions required to produce this effect. Presumably, ice of this nature can persist into the next year's ice season. However, this is not always the case, as demonstrated by the October 4, 1972 image.

The October 1972 image (Figure 9), although not related to the sequence described above, demonstrated early freeze-up conditions. From this image it can be seen how the near shore ice forms in successive bands. Although young ice may be formed over quite an extensive area, only the most protected ice remains fixed in location. Portions of new ice are broken off and drift under the influence of wind and currents. This mechanism repeats successively during the freeze-up period, accounting for the many bands of differently textured ice in the near shore areas.

### III. Discussion

It can be seen that throughout the year there is a series of ice conditions representing hazards to operations related to offshore petroleum exploration and extraction activities. These will be discussed in terms of each season.

Freeze-up (October-January): During this time there is not a clear distinction between a shorefast zone and pack ice. Hummock fields, shear and pressure ridges form in all near shore areas, providing load-bearing surfaces with large cross-sectional areas. Consequently, large

forces may be impressed on obstructions to ice motion regardless of their location. It would be extremely difficult, for example, to maintain a barge or drill ship in a desired location during this time. Modes of travel to offshore locations would be restricted to airborne methods. Bottom-fast structures may be subjected to rather large lateral forces.

Post Freeze-up (February-April): The most stable ice conditions are found during this time. Once the grounded features which define the shorefast zone are established, that area becomes suitable for surface travel. Further, bottom-fast structures within this area could be protected from large forces even if they did develop in that zone by means of a number of artificial strain-release mechanisms. (For instance, explosives could be used to eliminate physical continuity of the ice.) During this period there is also the greatest likelihood of stability of ice beyond the shorefast ice ... perhaps affording a temporary platform for seismic exploration.

Spring (April-May): Shear becomes active along the edge of the shorefast ice. There is some danger of transmission of forces to points within the shorefast ice and consequent strain release within this zone (Stringer, 1974). Beyond the shorefast ice great lateral forces can be exerted by moving pack ice.

Melt Season (June-July): Shear continues beyond the shorefast ice. Within the shorefast zone ice movement takes place by non-grounded ice. Such occurrences have been observed on the satellite data (Stringer, 1974) and by radar (Sackinger et al., 1974). Severe ice conditions may develop within the shorefast zone resulting from summer storms.

Ice-Free Season (August-September): This period is generally the span of time that the coastal area is ice free. However, this condition is not entirely dependable as was demonstrated by the September 6, 1974 image (Figure 8). During this time the entire coastal area is prone to severe ice conditions resulting from storms. The well-known Beaufort Sea storm surge beach ridges offer testimony that these events do occur.

It is interesting to speculate on the effect of a number of man-made structures placed in the near shore areas. If placed within the present shorefast zone, the effect could be that of increased hummocking in their vicinity and greatly increased stability of the ice sheet within the perimeter defined by the structures. In the extreme case there might be a tendency for the ice within this perimeter to become permanent. If placed beyond the present boundary of shorefast ice, man-made structures could very likely move the edge of shorefast ice out to that location. In either case, in the ice-free season the structures would serve the same purpose as the grounded ice fragments during that period and result in large groups of ice floes forming a barrier to seaward.

#### IV. Implications: Effects of Ice on Offshore Operations

If petroleum exploration is initiated from floating drillships, as is planned for the Canadian Beaufort Sea, drilling can proceed only during the ice-free (less than 10% ice cover) periods. Based upon the limited number of years of satellite and aircraft observation data available, this can range from approximately eight months in the St. George Basin of the Bering Sea to a mean of 28 days in the Prudhoe Bay area of the Beaufort Sea. Anomalous weather conditions can shorten or

segment these ice-free periods, as occurred in the summer of 1975 in the Beaufort Sea. Ice-reinforced drilling and resupply vessels would permit an extension of the drilling time and should be seriously considered. Exploration from gravity structures which could resist ice pressure would result in longer working periods, but platform service and resupply access would be primarily by helicopter, hovercraft, or in the case of shorefast ice, by wheeled vehicles over the ice after mid-winter. The shorefast ice zone is the safest region for winter drilling operations. On the prevailing side of coasts and islands, or indeed beyond the shorefast ice in water deeper than 20 meters, ice pressures are more severe and virtually continuous.

Eventual production would require the development of subsea production equipment which can withstand occasional ice scour. Continuous petroleum production throughout the year from the western coast of Alaska will be likely to require a fleet of ice-reinforced tankers, as well as an ice-resistant deepwater loading terminal offshore. For the annual ice encountered in the Bering Sea, this appears to be within the capabilities of present technology, although the existence of sufficient reserves, together with the economics of the situation, remain to be determined. The relationship between ice motion and meteorological variables would be operationally important, so that accurate ice forecasts could be made.

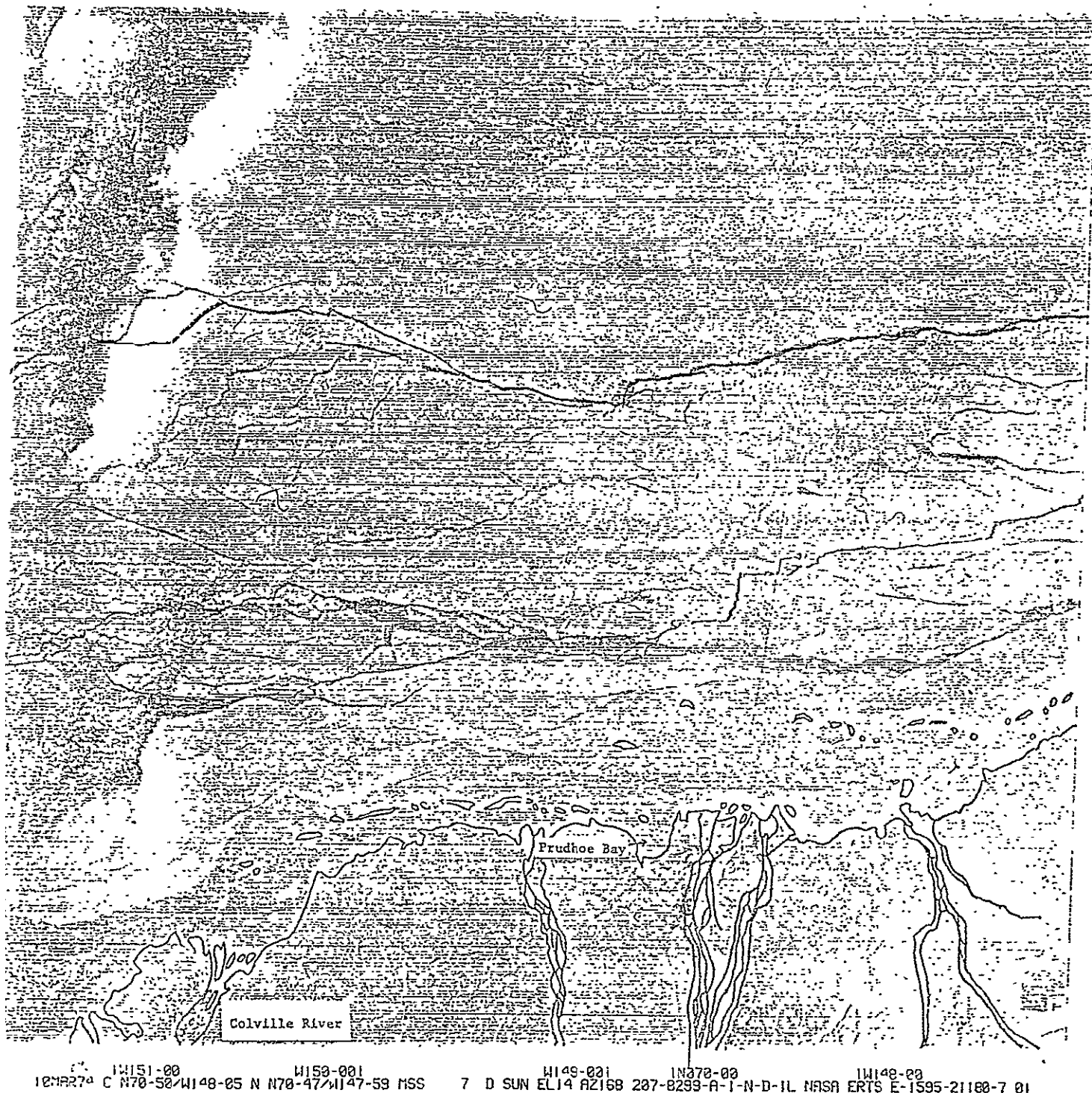
#### ACKNOWLEDGMENTS

The research reported here was supported in part by NASA Grant NAS5-20959 and OCSEAP 03-5-022-55.

## REFERENCES

- Brooks, L. D., Ice Scour on Northern Continental Shelf of Alaska, Proceedings of the Symposium on Beaufort Sea Coast and Shelf Research, Arctic Institute of North America, 355-366, 1974.
- Hudson, T. A., Arctic Offshore Data Gaps and How to Fill Them, Offshore Technology Conference, Houston, Texas, May 1973.
- Kovacs, A. and M. Mellor, Sea Ice Morphology and Ice as a Geologic Agent in the Southern Beaufort Sea, Proceedings of the Symposium on Beaufort Sea Coast and Shelf Research, Arctic Institute of North America, 113-162, 1974.
- Nelson, R. G. and W. M. Sackinger, Stresses in Sea Ice, 31st Petroleum ASME Conference, Mexico City, September 1976.
- Reimnitz, E., L. Toimil and P. Barnes, Development of the Stanukhi Zone and Its Relationship to Arctic Shelf Processes and Morphology, Beaufort Sea, Alaska (preprint), 1976.
- Sackinger, W. M., J. C. Rogers and R. D. Nelson, Arctic Coastal Sea Ice Dynamics, Offshore Technology Conference, Houston, Texas, May 1974.
- Shapiro, L. H., A Preliminary Study of the Formations of LANDSAT Ice at Barrow, Alaska, Winter 1973-1974, Geophysical Institute Report UAG R-235, Sea Grant Report No. 75-7, June 1975.
- Stringer, W. J., Shorefast Ice in the Vicinity of Harrison Bay, The Northern Engineer, Vol. 5, No. 4, Winter 1973/1974.
- Stringer, W. J. and S. A. Barrett, Ice Motion in the Vicinity of a Grounded Floeberg, Proceedings of the Third Conference on Port and Ocean Engineering under Arctic Conditions, University of Alaska (in press), 1976.
- Stringer, W. J., The Morphology of Beaufort Sea Shorefast Ice, Proceedings of the Symposium on Beaufort Sea Coast and Shelf Research, Arctic Institute of North America, 165-172, 1974.





104151-00 104153-001 104149-021 104148-00 104148-00  
104148-00 C N70-52/104148-05 N N70-47/104147-59 MSS 7 D SUN EL14 AZ168 287-8293-A-1-N-D-IL NASA ERTS E-1595-21180-7 01

Figure 1: Landsat image 1595-21180 obtained 10 March, 1974 showing near-shore ice from the Colville River eastward to the vicinity of Flaxman Island.

ORIGINAL PAGE IS  
OF POOR QUALITY

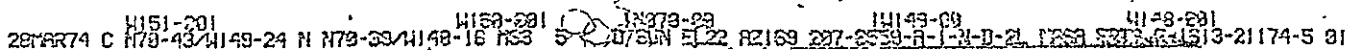
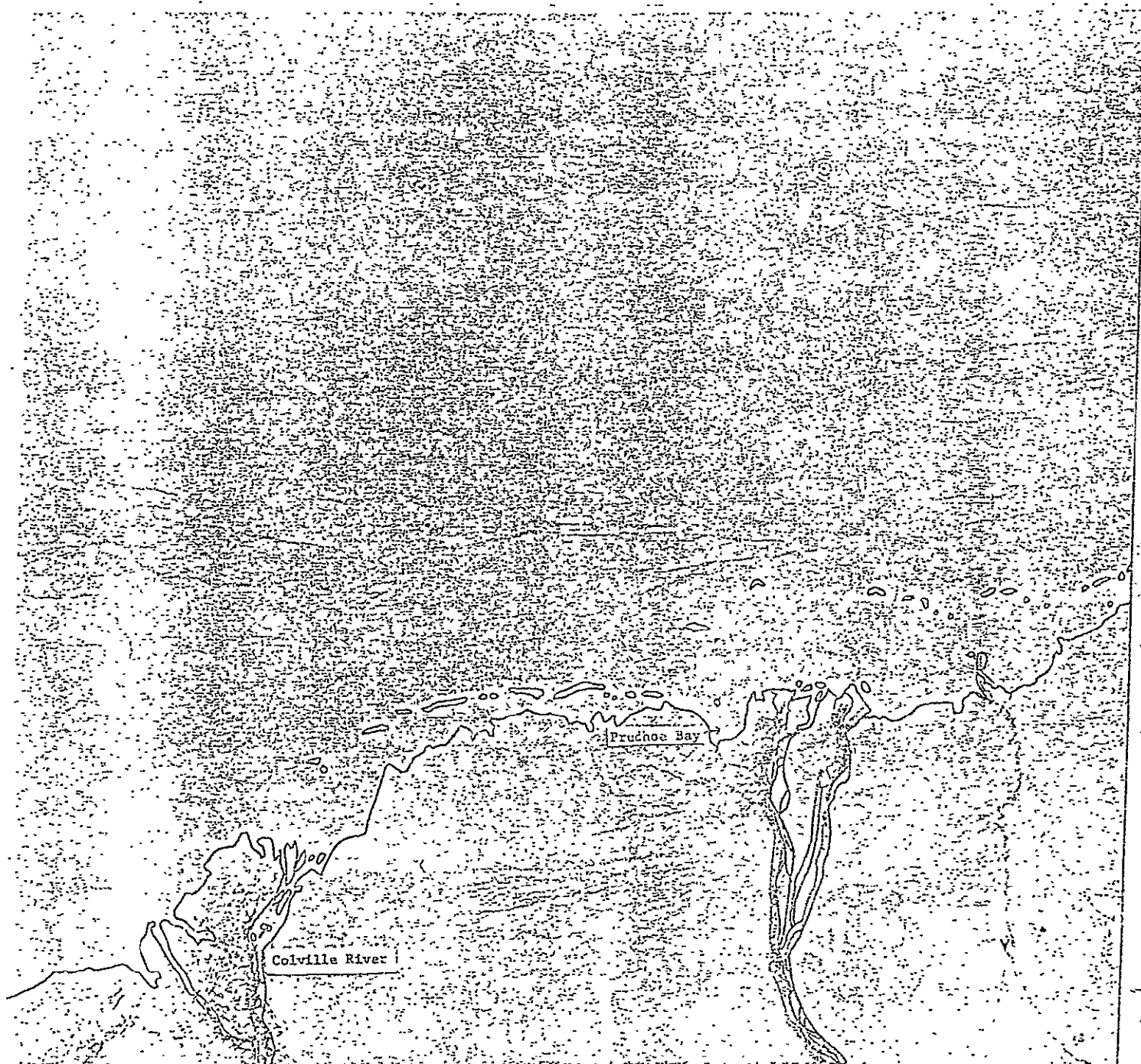


Figure 2: Landsat image 1613-21174 obtained 28 March, 1974 showing near-shore ice from the Colville River eastward to the vicinity of Flaxman Island.

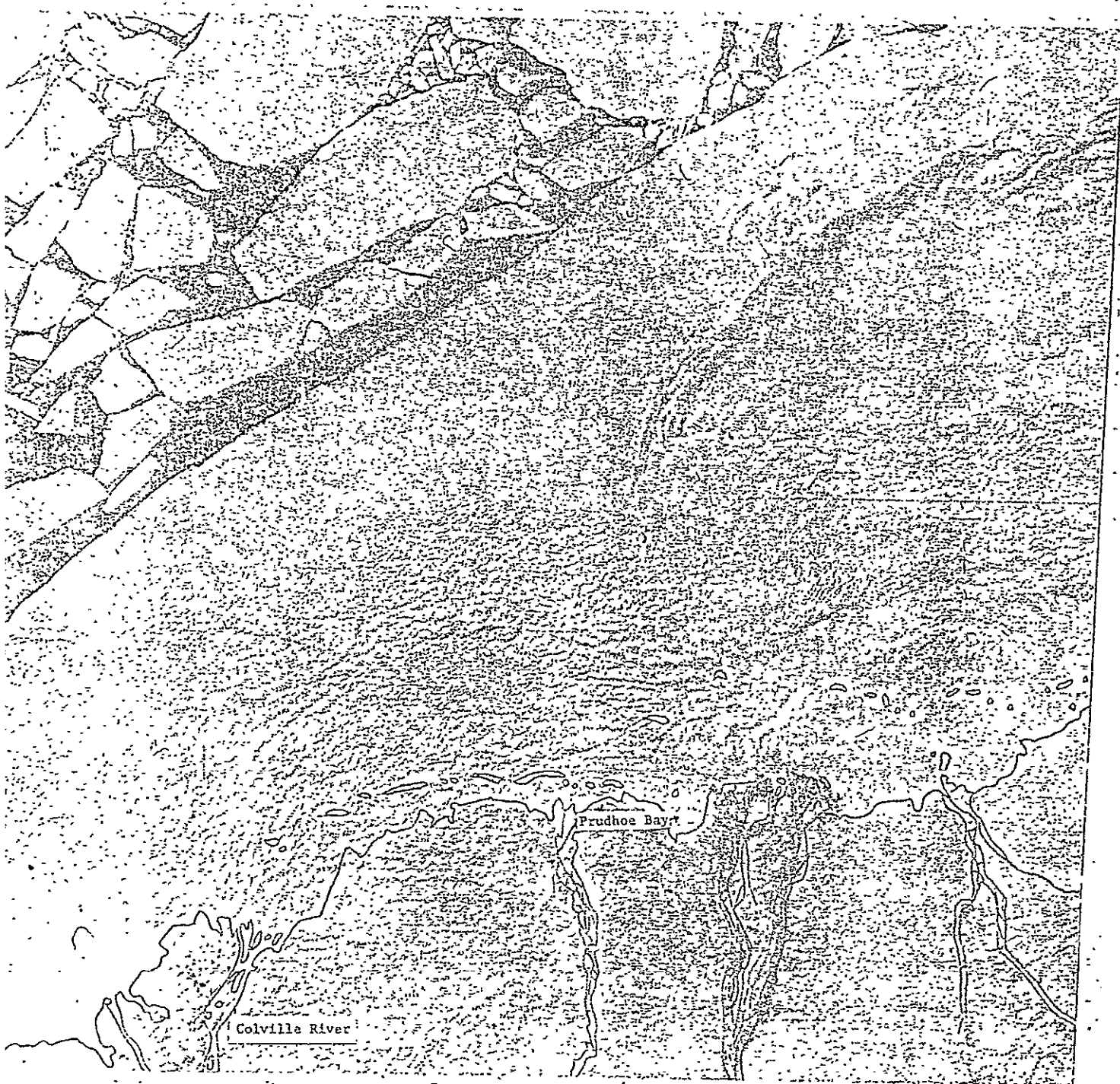
ORIGINAL PAGE IS  
OF POOR QUALITY



1151-001 N070-001 1W150-00 N149-001 1149-001  
63 MAY 74 C N73-41/W149-43 N N70-37/W149-22 MSS 7 D SUN EL34 RZ170 237-9652-A-1-N-D-IL NASA ERTS-E-153-21165-7 01

Figure 3: Landsat image 1649-21165 obtained 3 May, 1974 showing near-shore ice from the Colville River eastward to the vicinity of Flaxman Island.

ORIGINAL PAGE IS  
OF POOR QUALITY



21MAY74 C N79-49 W149-28 N N79-44 W149-11 MSS 7 D SUN EL30 R2179 237-5323-R-1-N-D-IL NASA ERTS S-1637-21152-7 92

Figure 4: Landsat image 1667-21162 obtained 21 May, 1974 showing near-shore ice from the Colville River eastward to the vicinity of Flaxman Island.

ORIGINAL PAGE IS  
OF POOR QUALITY



1W152-22 1W149-031 1W149-001 N272-231 1W147-02  
25JUN74 C N73-53/W145-59 N N73-49/W146-37 MSS 7 D SUN EL42 R2167 287-9791-R-I-N-D-IL NASA ERTS E-1702-2:393-7 02

Figure 5: Landsat image 1702-21093 obtained 25 June, 1974 showing near-shore ice from the Colville River eastward to the vicinity of Flaxman Island.



ORIGINAL PAGE IS  
OF POOR QUALITY



12051-00 WISD-221 163-221 M872-221 2128-221  
25-0000 17 N 170-58/48-01 MSS 7 D SUN EL42 AZ167 227-9035-A-1-N-D-1L NMSR ERTS E-1703-21151-7 01

Figure 6: Landsat image 1703-21151 obtained 26 June, 1974 showing near-shore ice from the Colville River eastward to the vicinity of Flaxman Island.

ORIGINAL PAGE IS  
OF POOR QUALITY



1400000 0 1721-21143-27 1 1721-21143-27 1721-21143-27 1721-21143-27 1721-21143-27 1721-21143-27 1721-21143-27 1721-21143-27 1721-21143-27 1721-21143-27

Figure 7: Landsat image 1721-21143 obtained 14 July, 1974 showing near-shore ice from the Colville River eastward to the vicinity of Flaxman Island.



Figure 8: Landsat image 1775-21124 obtained 6 September, 1974 showing near-shore ice from the Colville River eastward to the vicinity of Flaxman Island.



ORIGINAL PAGE IS  
OF POOR QUALITY

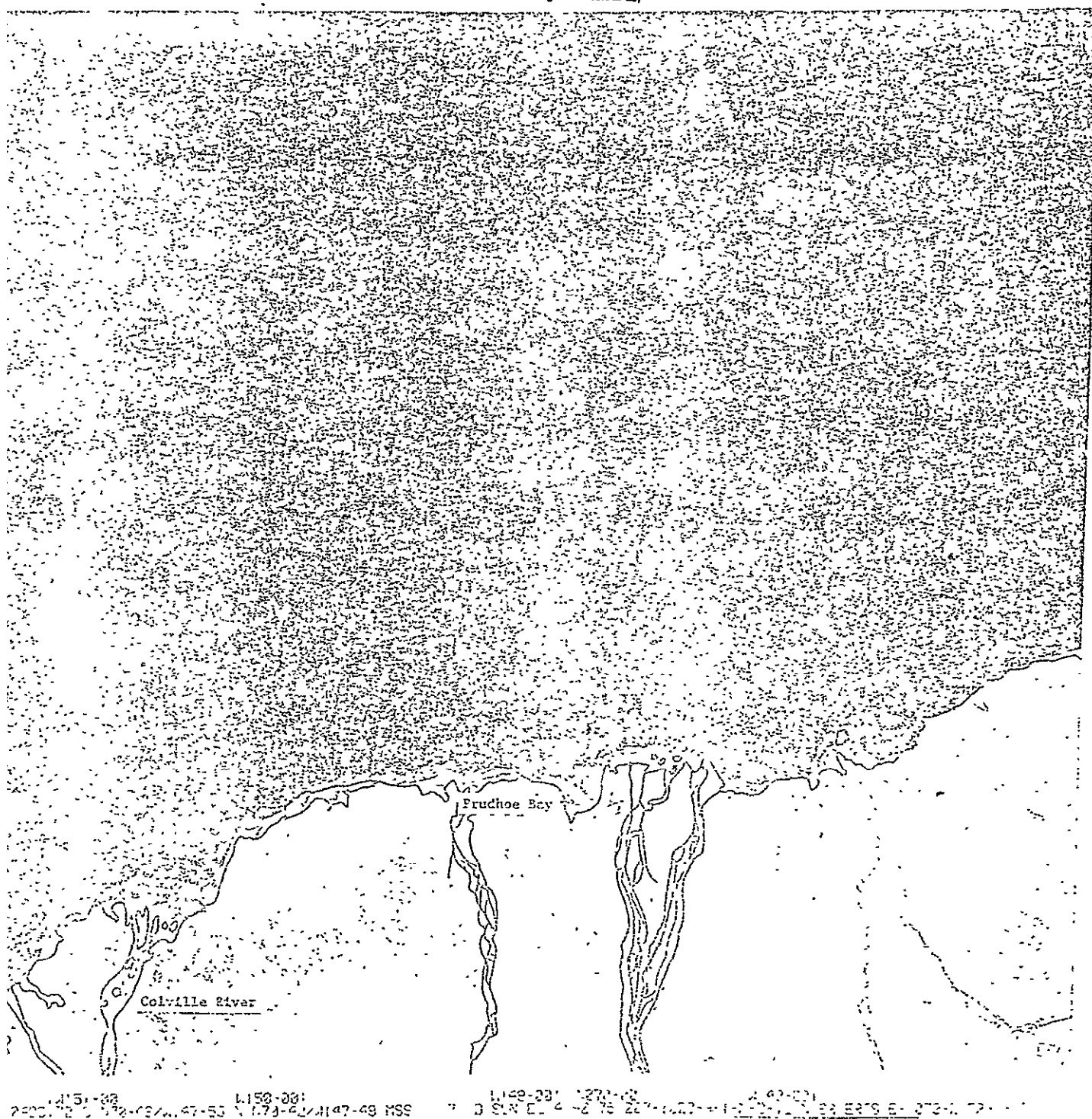
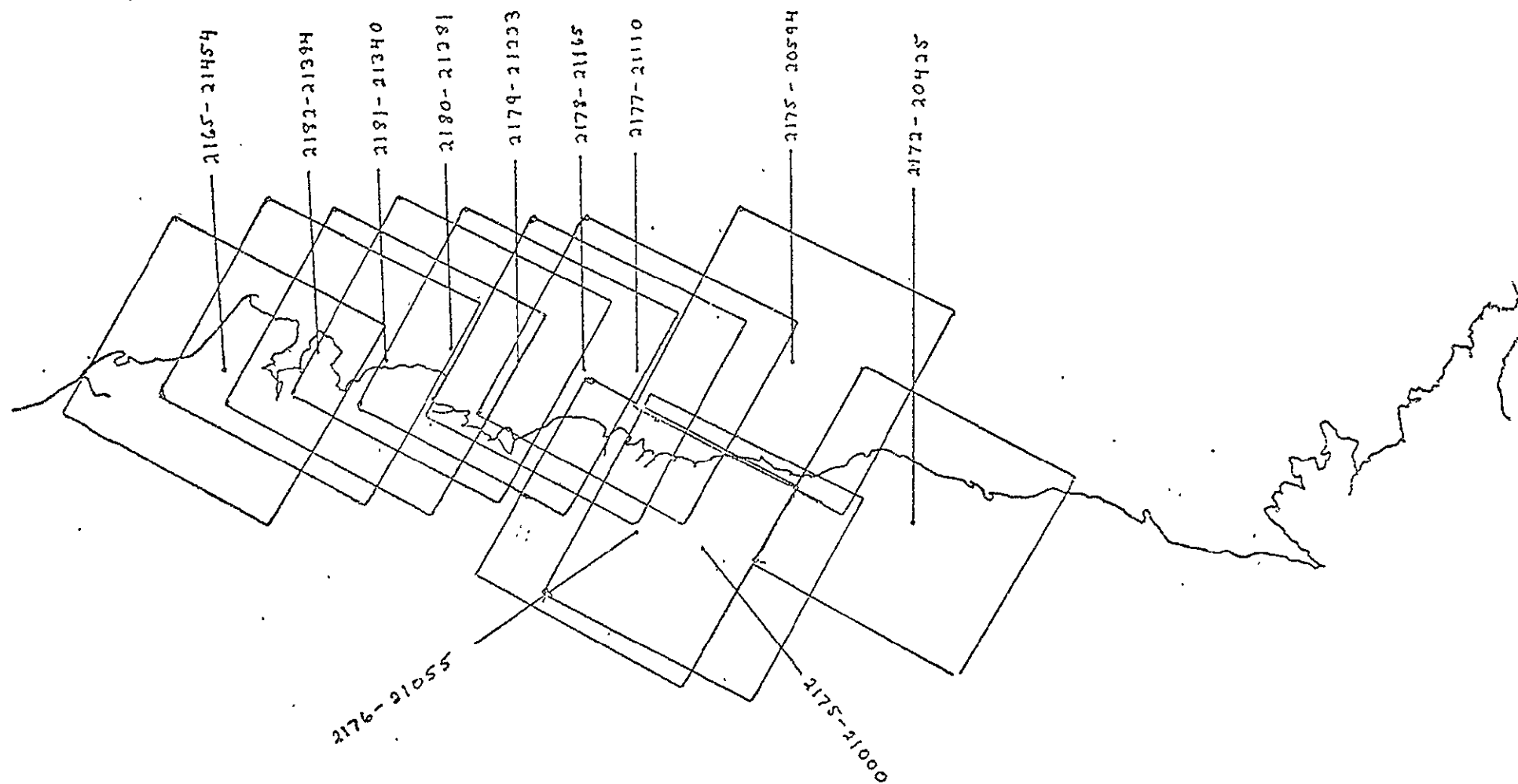


Figure 9: Landsat image 1073-21223 obtained 4 October, 1972 showing near-shore ice from the Colville River eastward to the vicinity of Flaxman Island.

74



BEAUFORT SEA

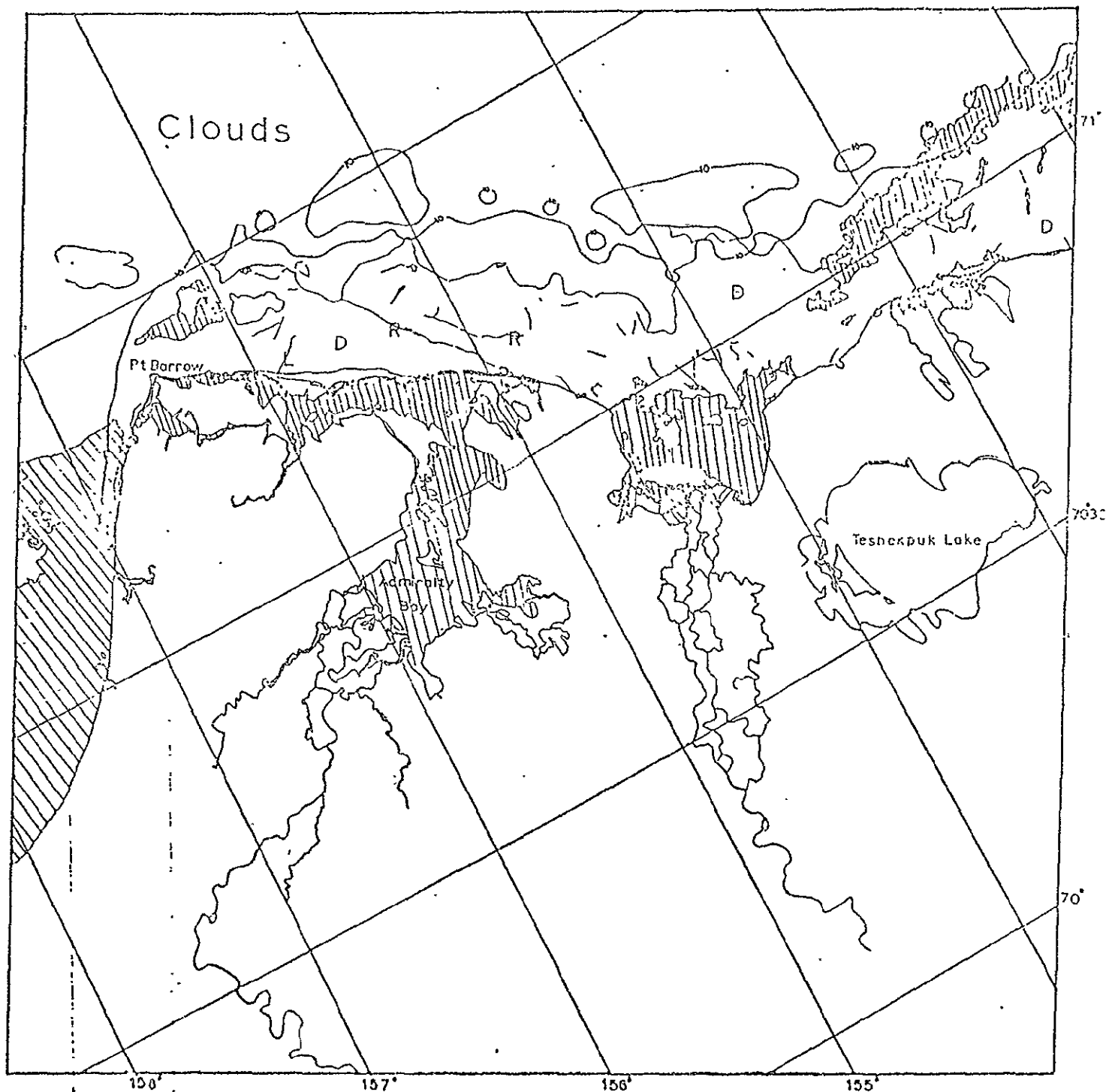
6 JULY - 23 JULY 1975

Images 2165 - 2182

Scenes 2172-20425 through 2182-21394

These scenes show the Beaufort Sea Coast between July 13-23, 1975. The chief value of this summer imagery is the identification of ice features remaining in place in mid summer and therefore very likely grounded. Ice yet grounded at this date was probably well grounded much of the past ice season.

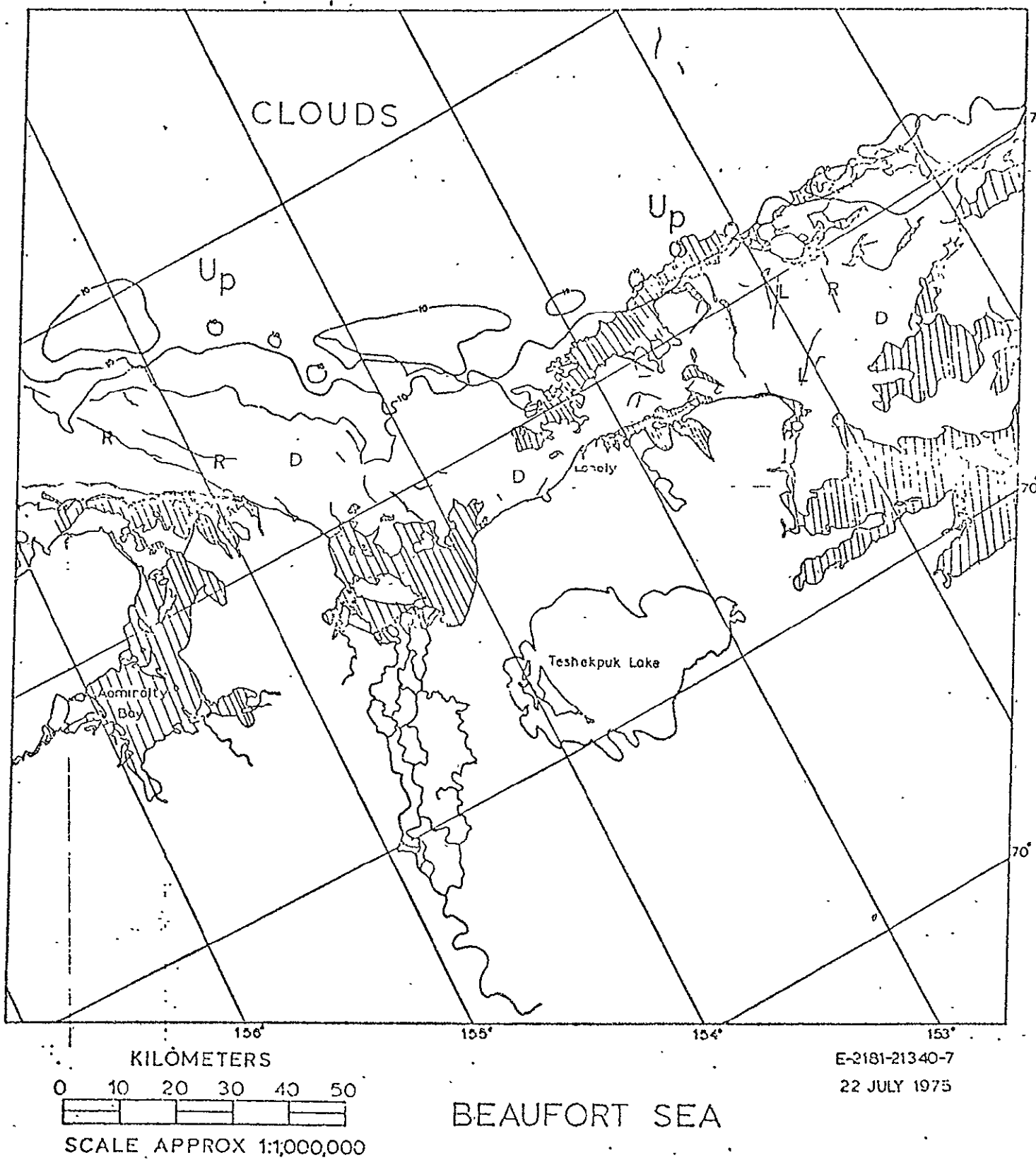
Although thin clouds obscure much of the coast, it is still possible to trace ice boundaries along much of the coast. Of particular interest in the Harrison Bay area is the large complex of apparently grounded ridges mapped far off shore.

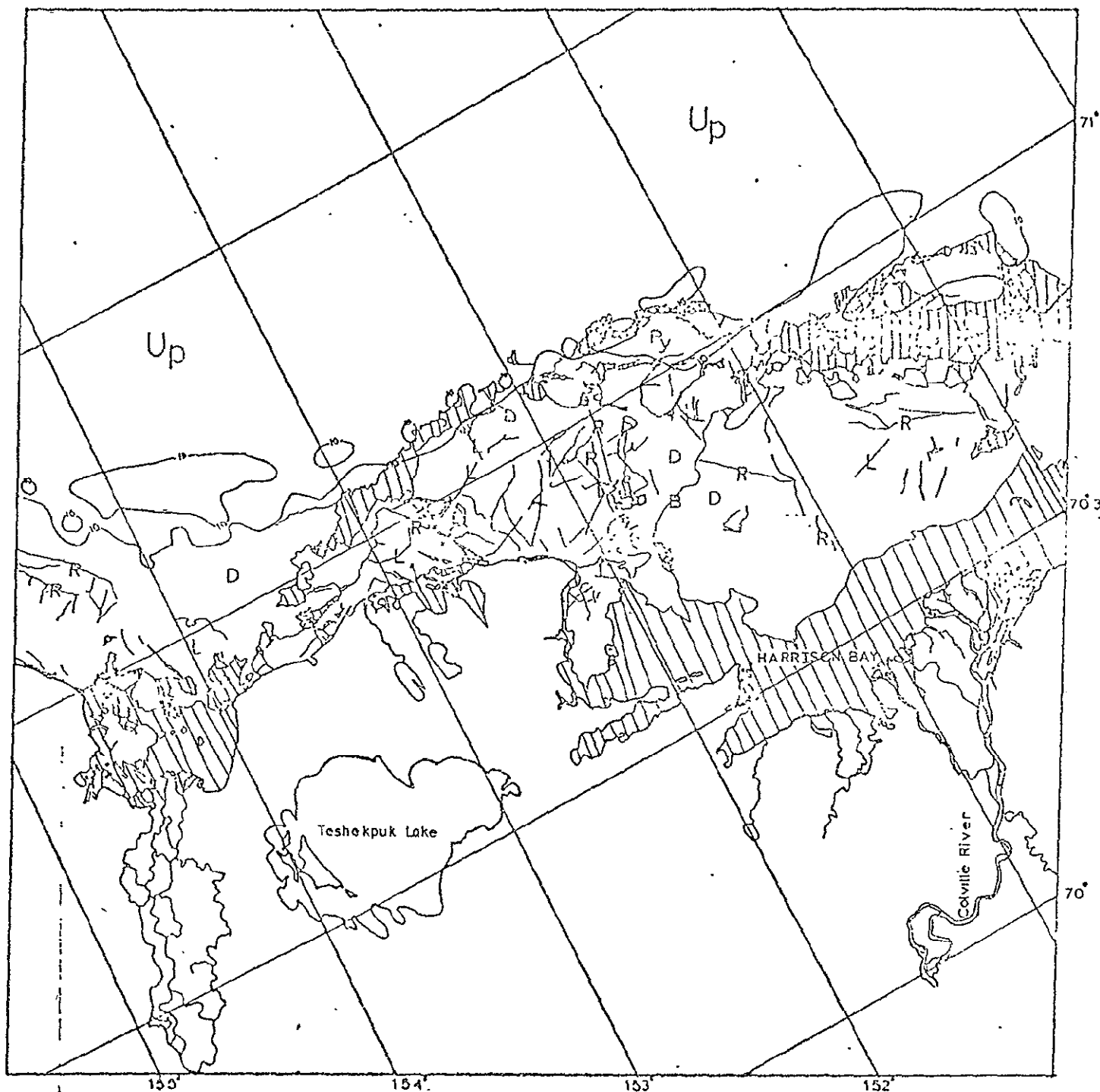


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-2182-21394-7  
23 JULY 1975

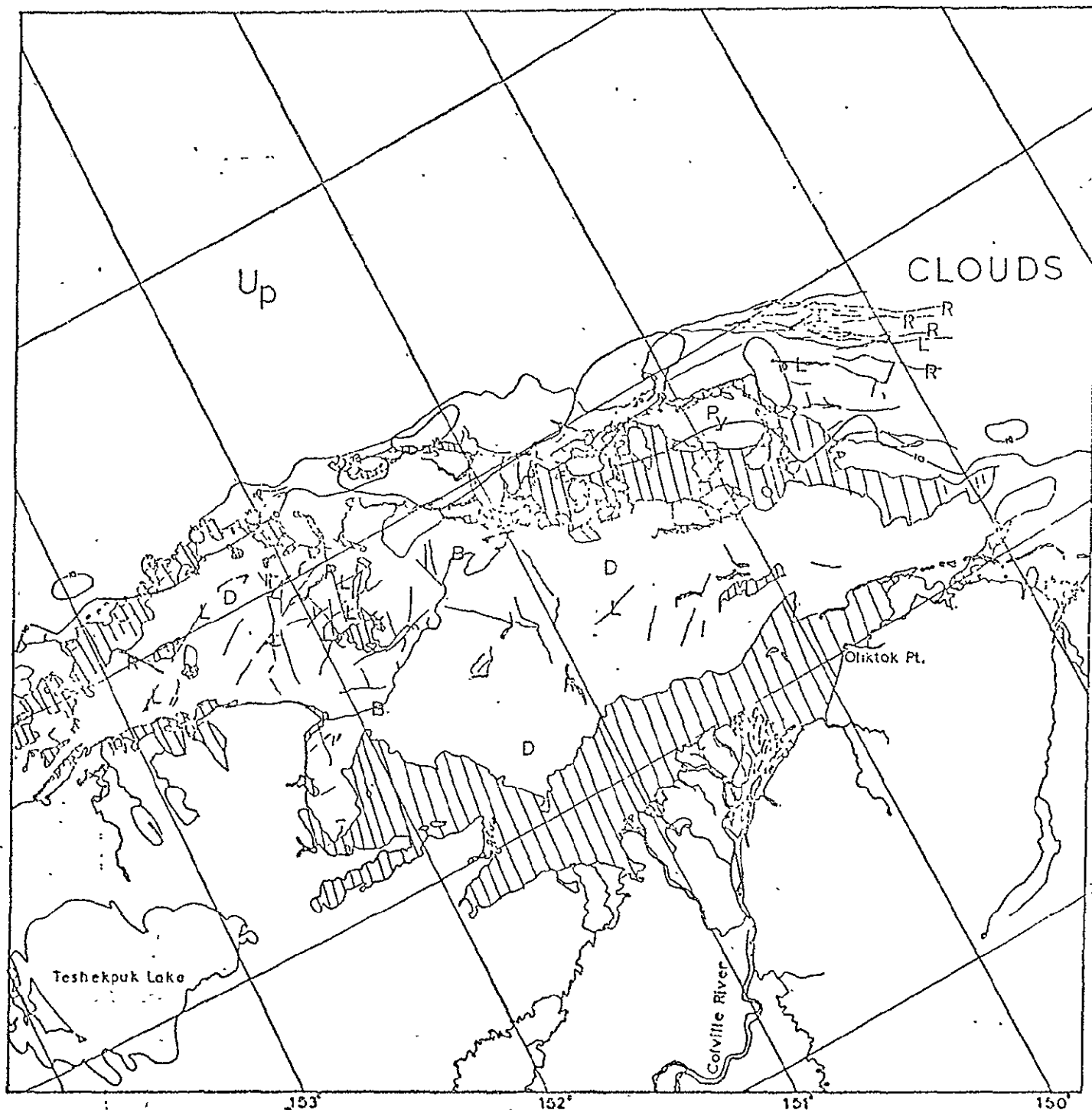


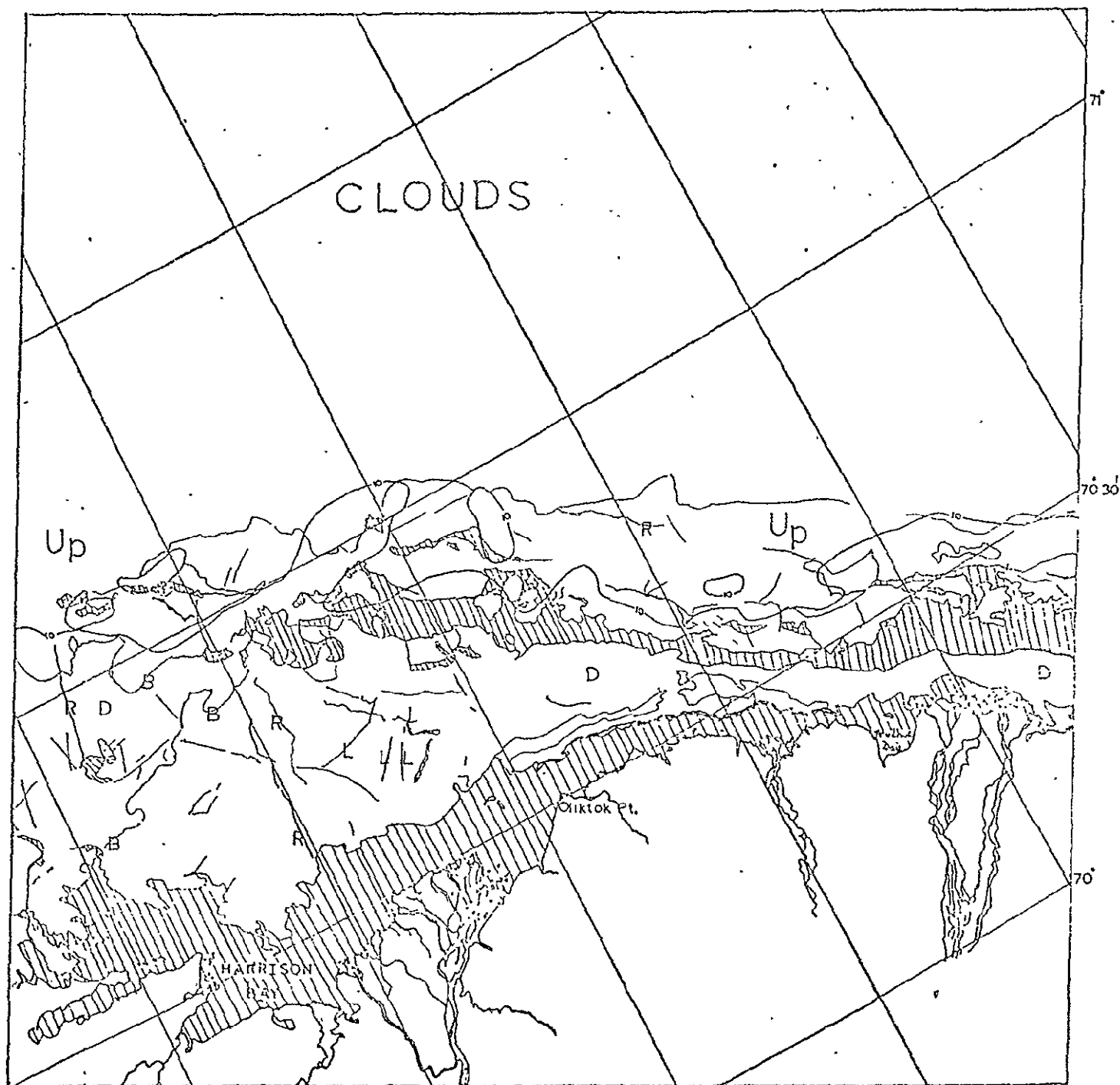


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-2180-21281-7  
21 JULY 1975



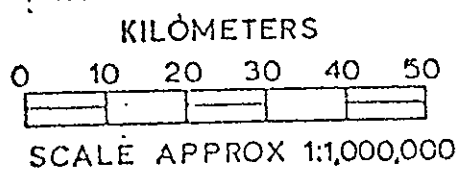


152° 151° 150° 149°  
 KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

BEAUFORT SEA

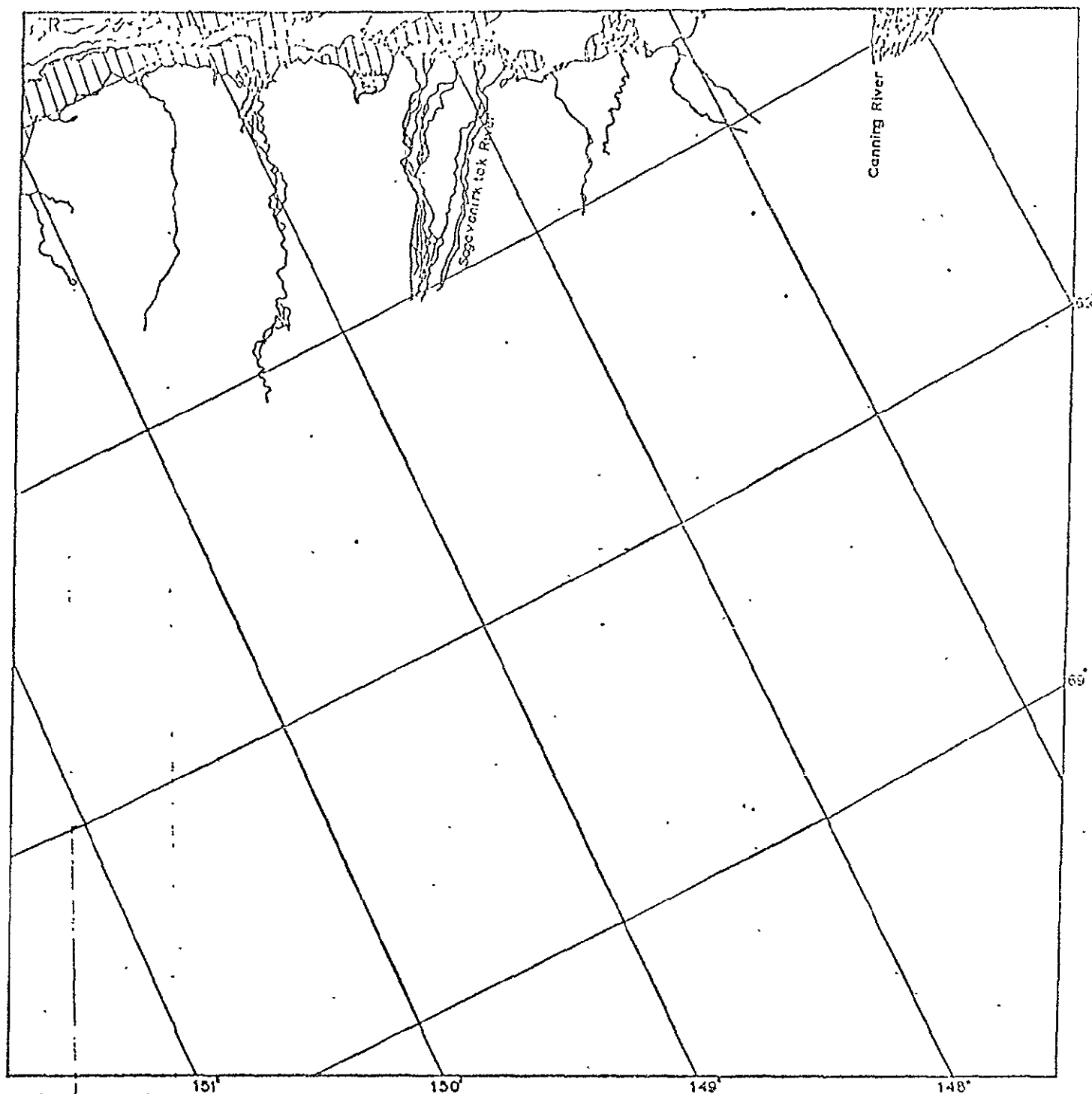
E-2178-21165-7  
 19 JULY 1975





E-2177-21110-7  
18 JULY 1975

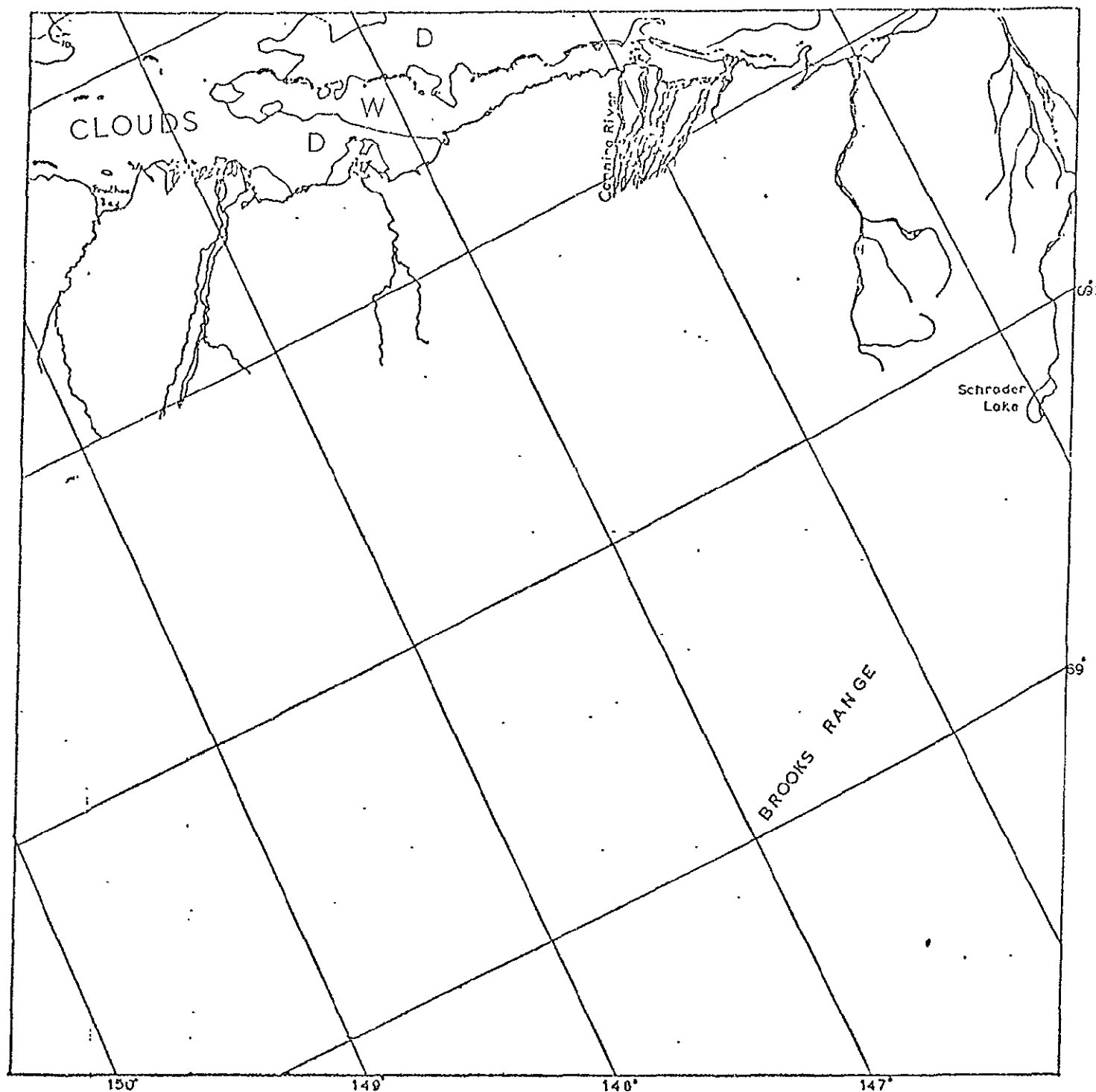
BEAUFORT SEA



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

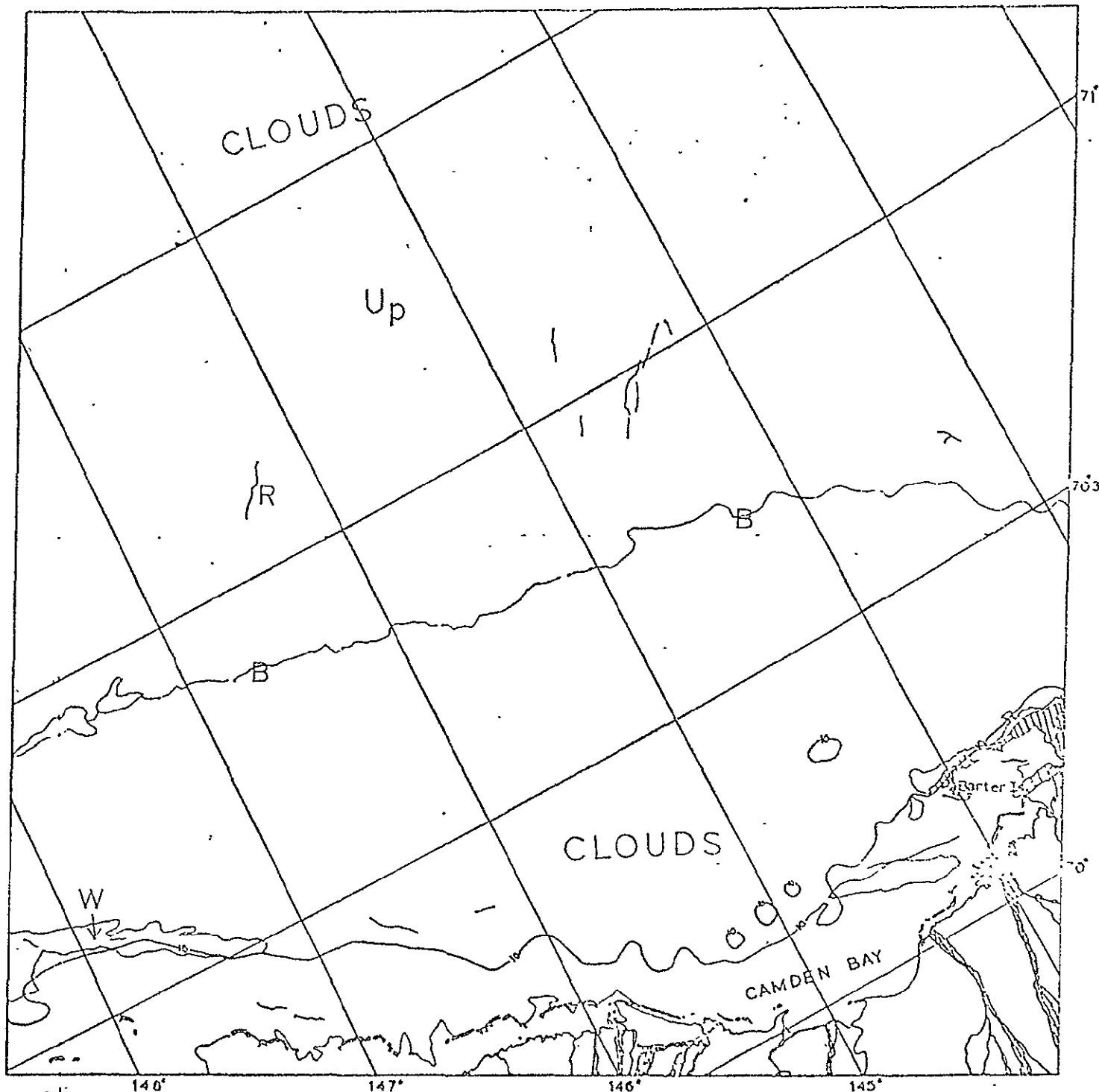
E-2176-21055-7  
17 JULY 1975

BEAUFORT SEA



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

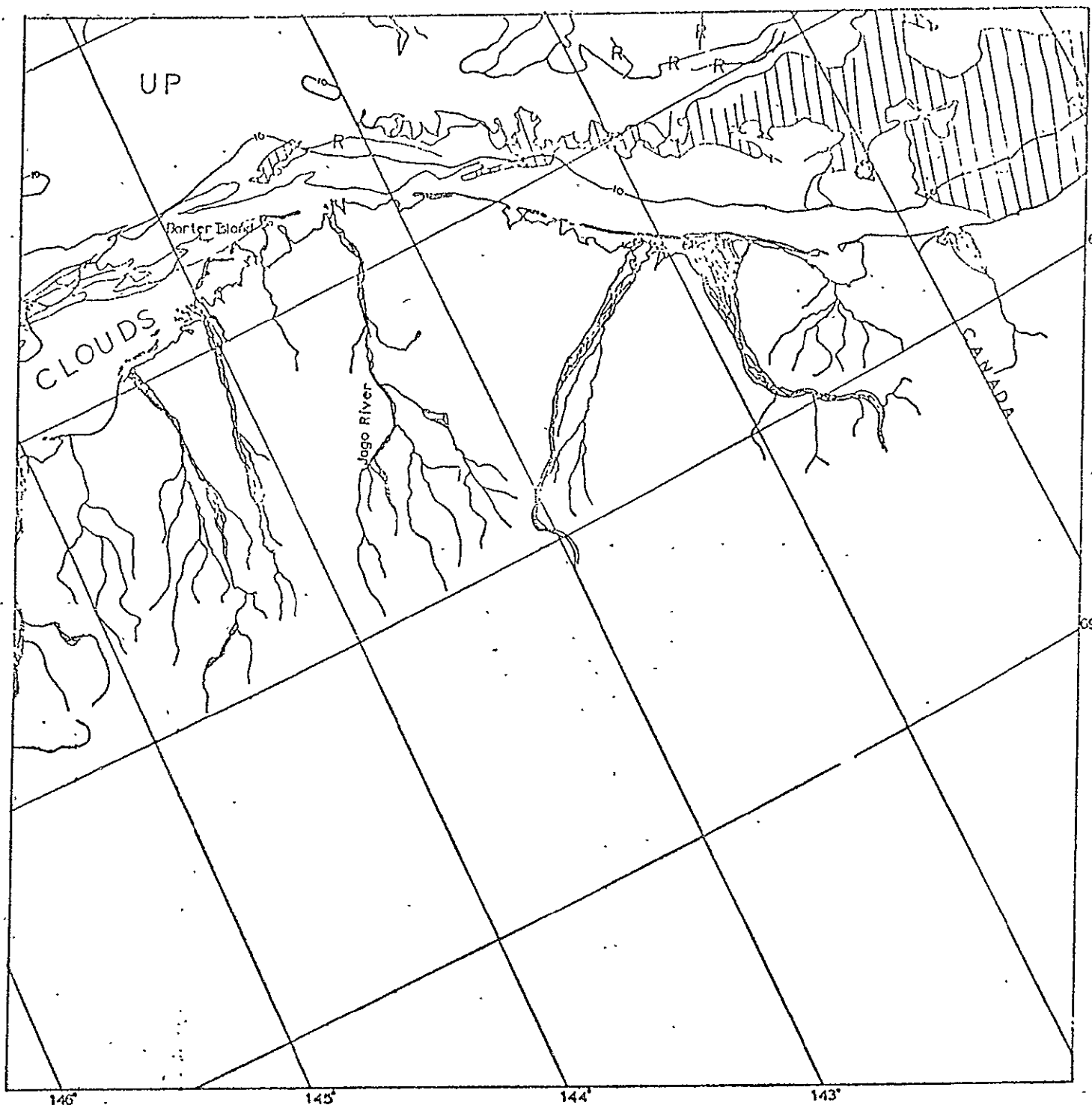
E-2175-21000-7  
 16 JULY 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-2175-20594-7  
18 JULY 1975



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

BEAUFORT SEA

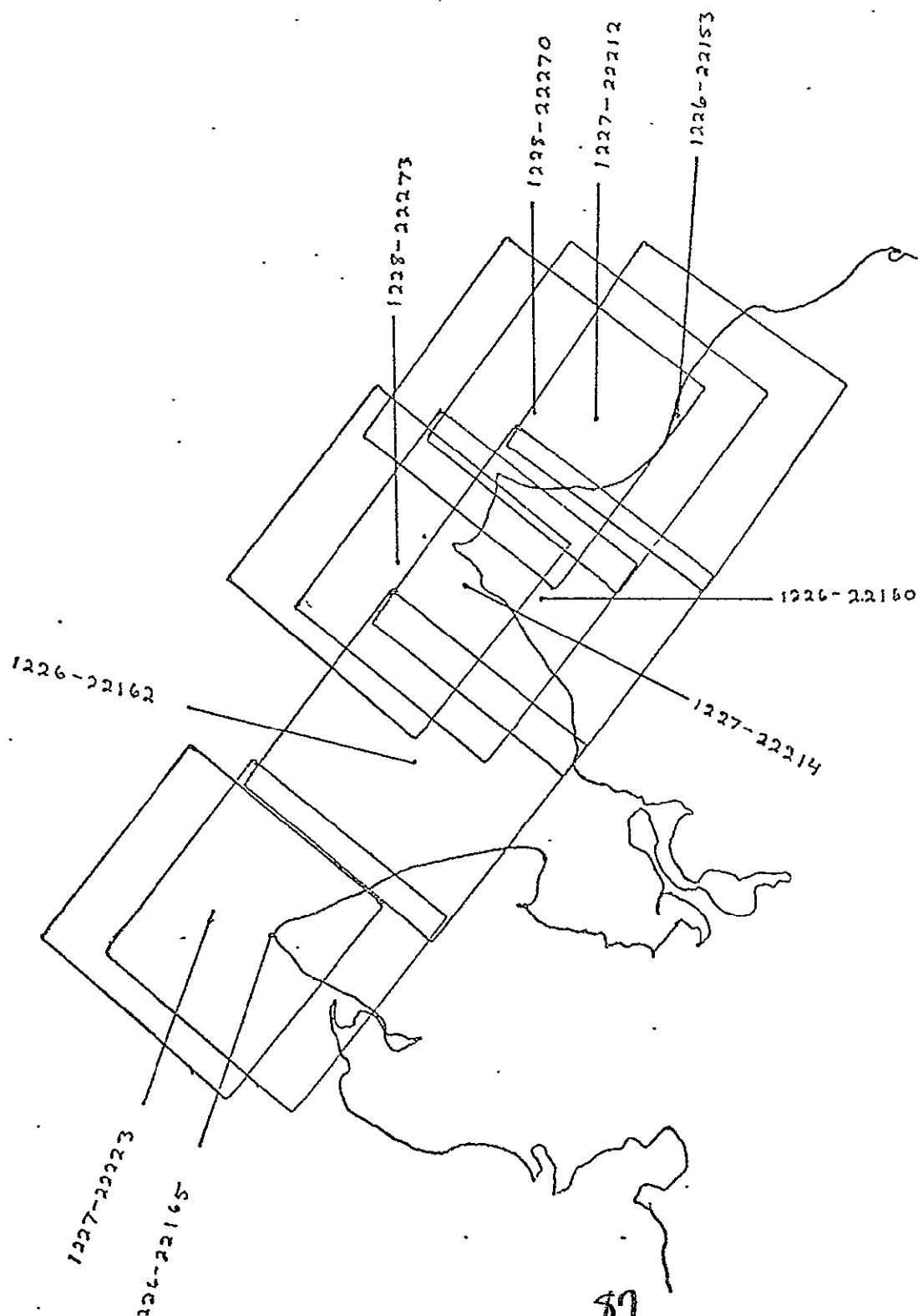
E-2172-20:257  
 13 JULY 1975



# CHUKCHI SEA

2 - 19 MARCH 1973

Images 1222 - 1239



Scenes 1226-22153 }  
1226-22160 } adjacent scenes  
1226-22162 }  
1226-22165 }  
1227-22214  
1227-22223  
1228-22270 } adjacent scenes  
1228-22273 }

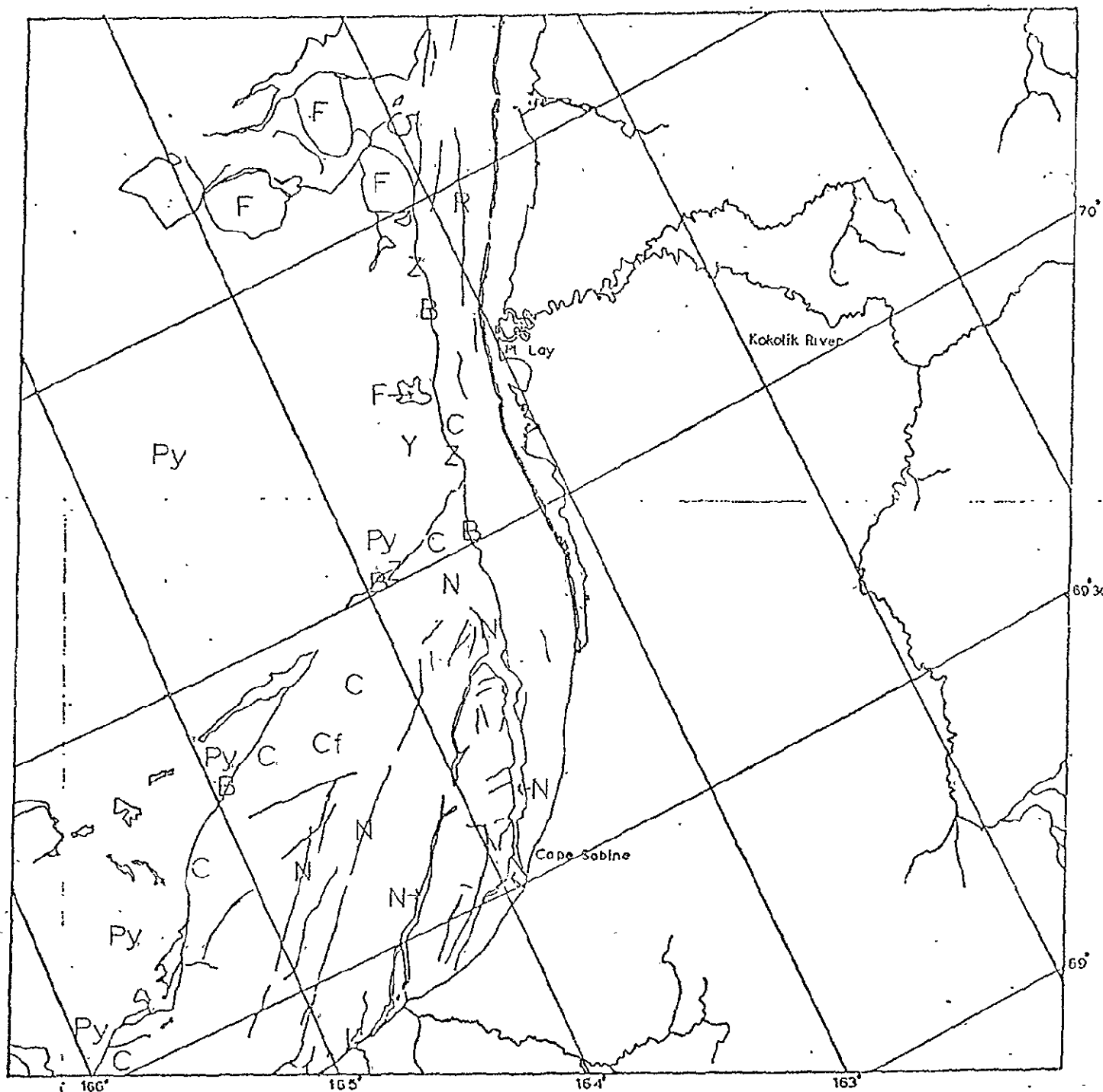
These scenes show the Point Lay to Cape Prince of Wales portion of the Chukchi coast between March 6-8, 1973. The configuration of oceanic ice indicates that several cycles of ice formation and subsequent breakage have taken place, with ice being driven out Bering Strait with a velocity of 0.6 km/hour or 17cm/sec.

There is a large expanse of contiguous ice extending northward from Cape Prince of Wales which may be grounded on shoals in that area. To the north, contiguous ice extends seaward both north and south of Point Hope. There is some evidence of large ridge systems on the seaward side of the contiguous ice to the north. However, from the north of that apron to Cape Lisburne there is no contiguous ice although the 10 fathom contour is considerably seaward of the coast.

To the north of Cape Lisburne the seaward edge of the contiguous ice roughly follows the 10-fathom contour. In the Point Lay area several ridges can be found parallel to the coast.

ORIGINAL PAGE IS  
OF POOR QUALITY

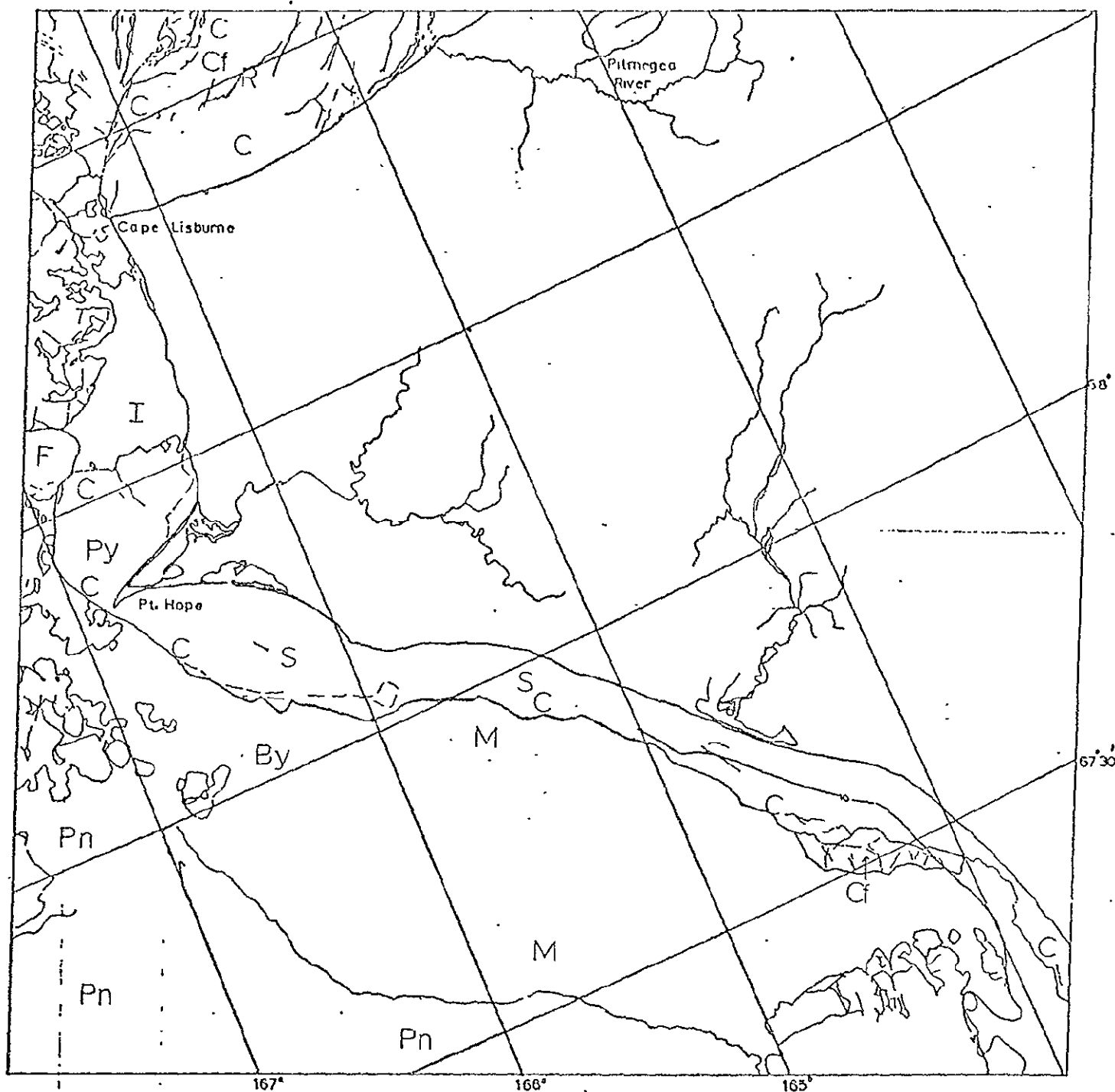




KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

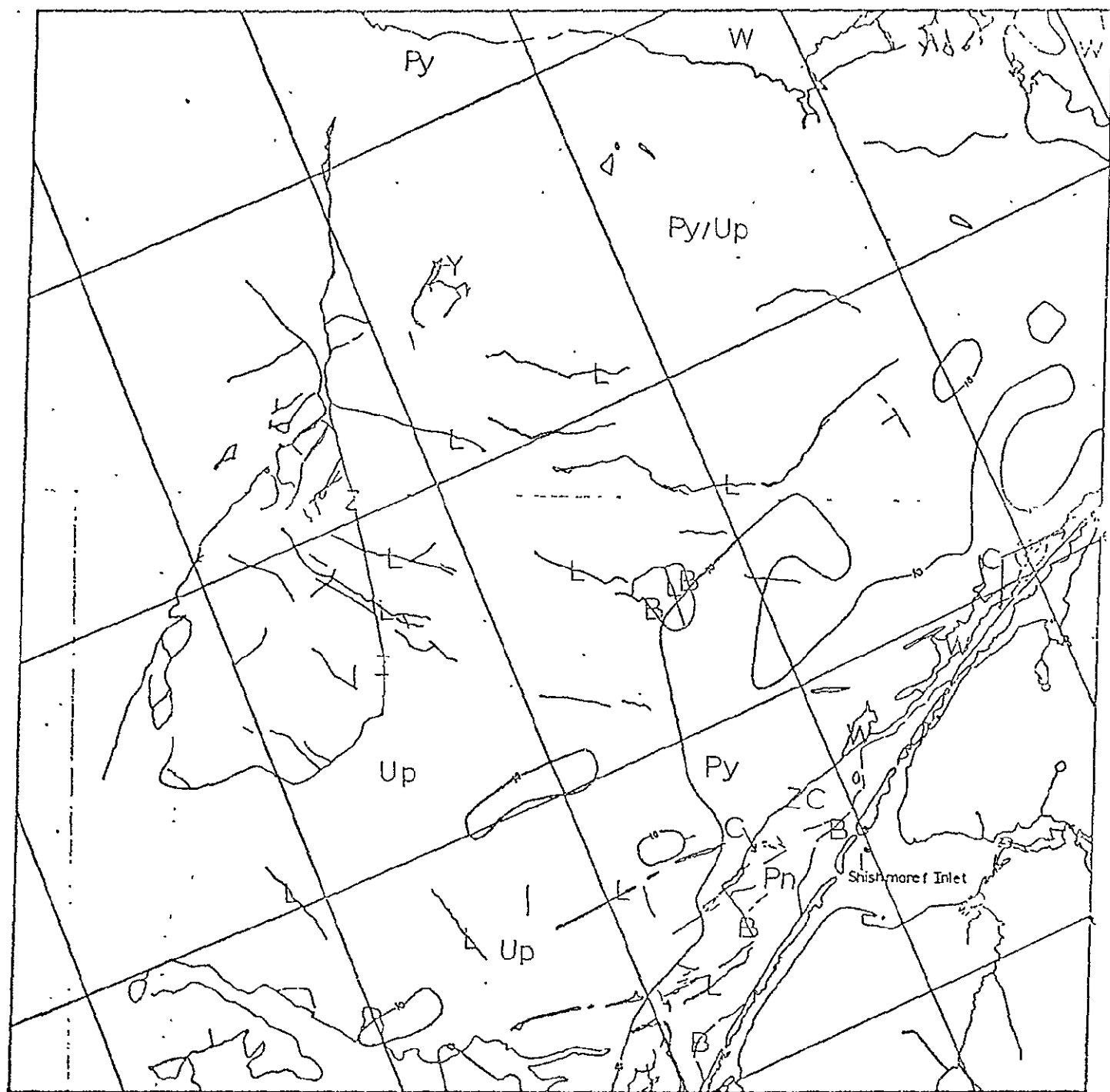
E-1226-22153-7  
6 MARCH 1973



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1226-22160-7  
 6 MARCH 1973



189° 100° 167°

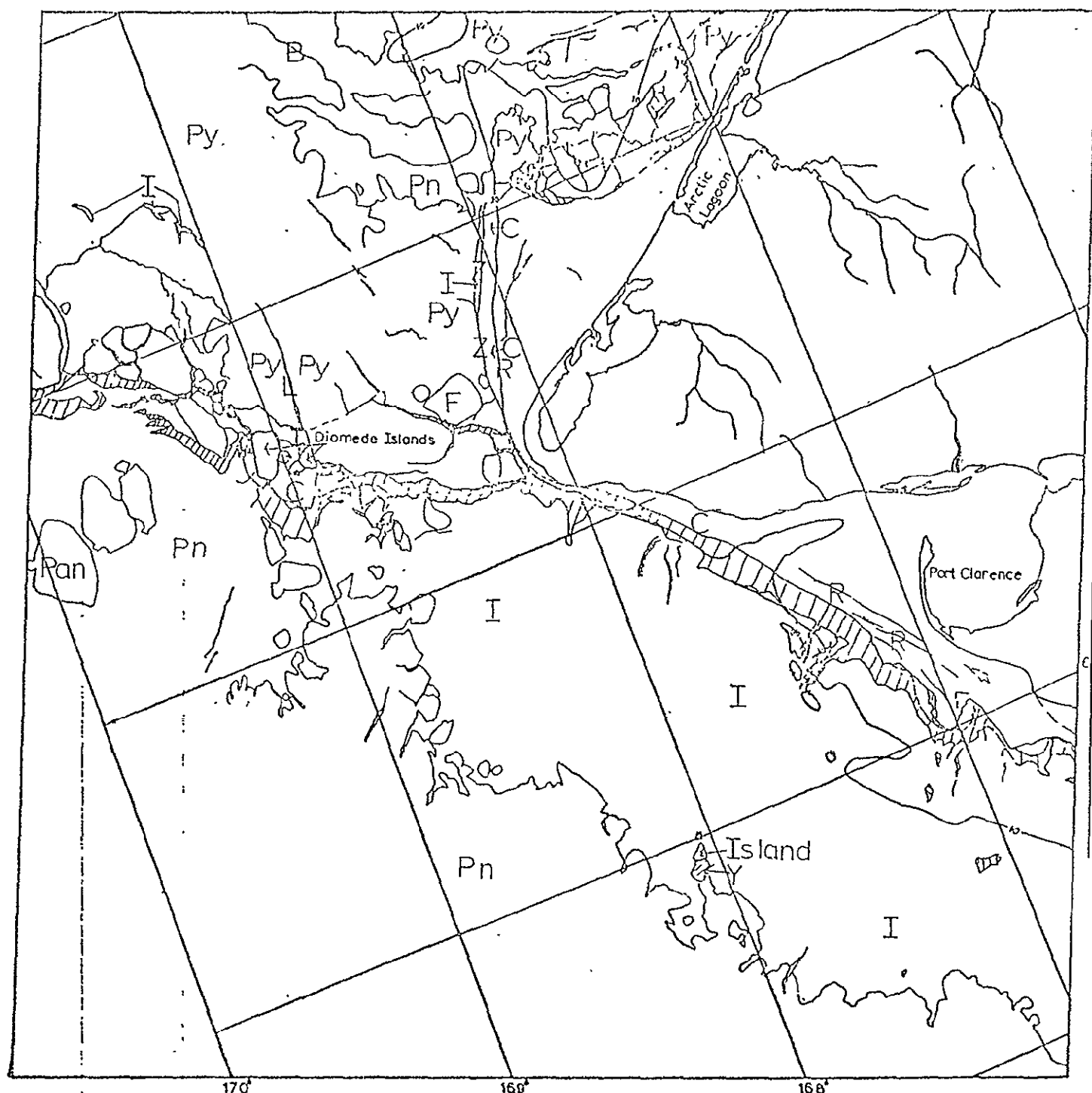
KILOMETERS

0 10 20 30 40 50

SCALE APPROX 1:1,000,000

CHUKCHI SEA

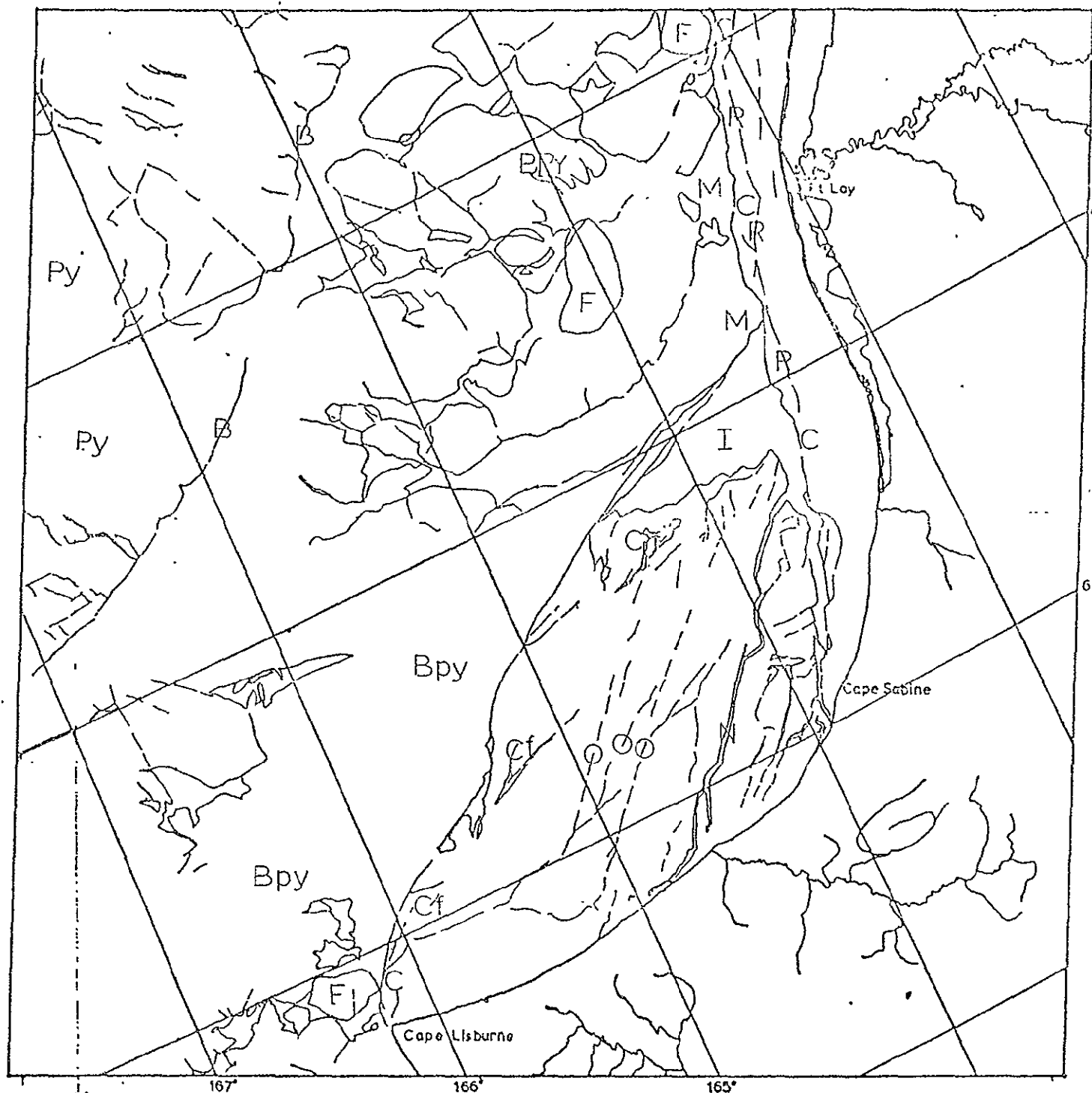
E-1226-22162-7  
6 MARCH 1973



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

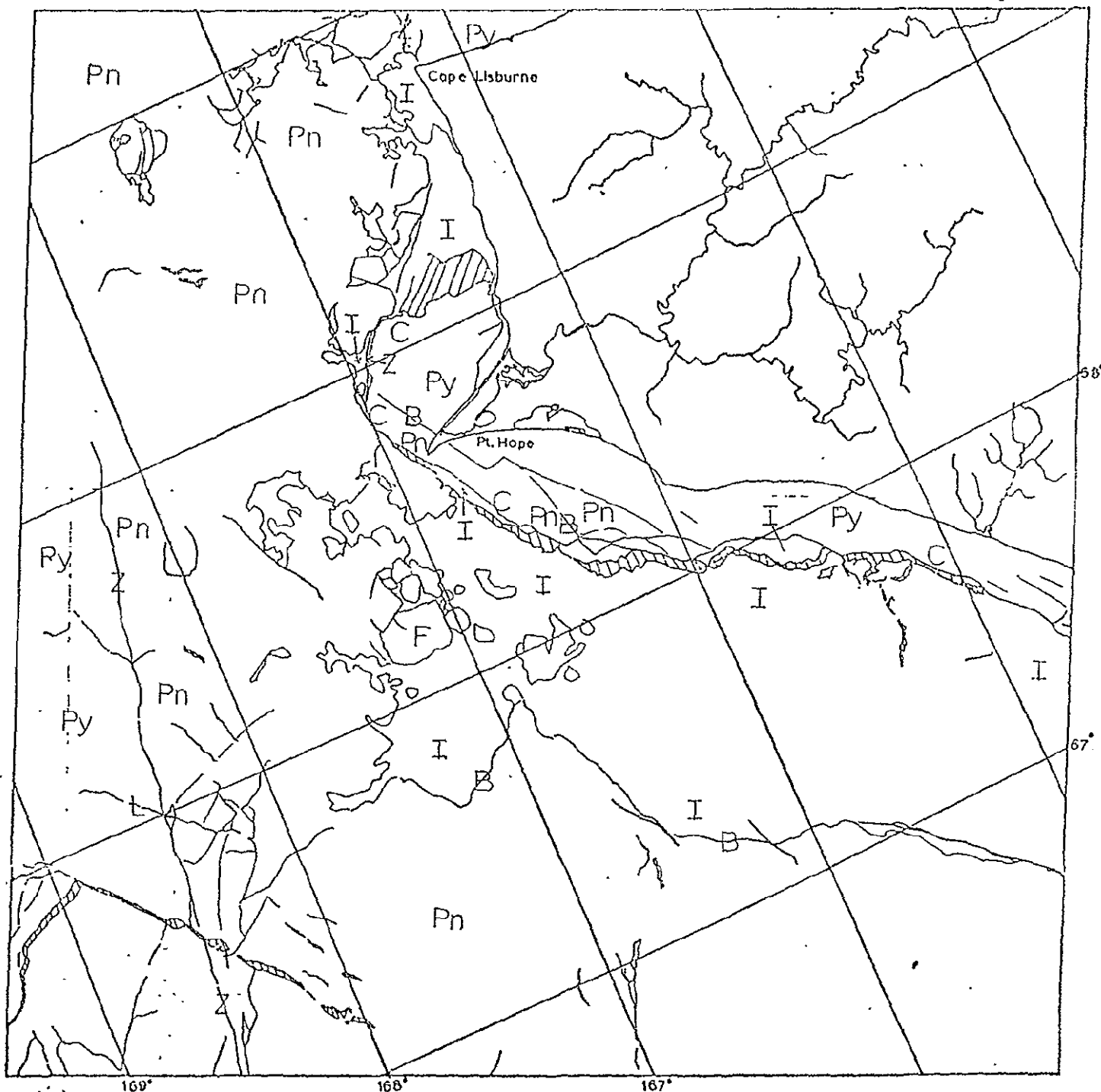
E-1226-22165-7  
 6 MARCH 1973



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

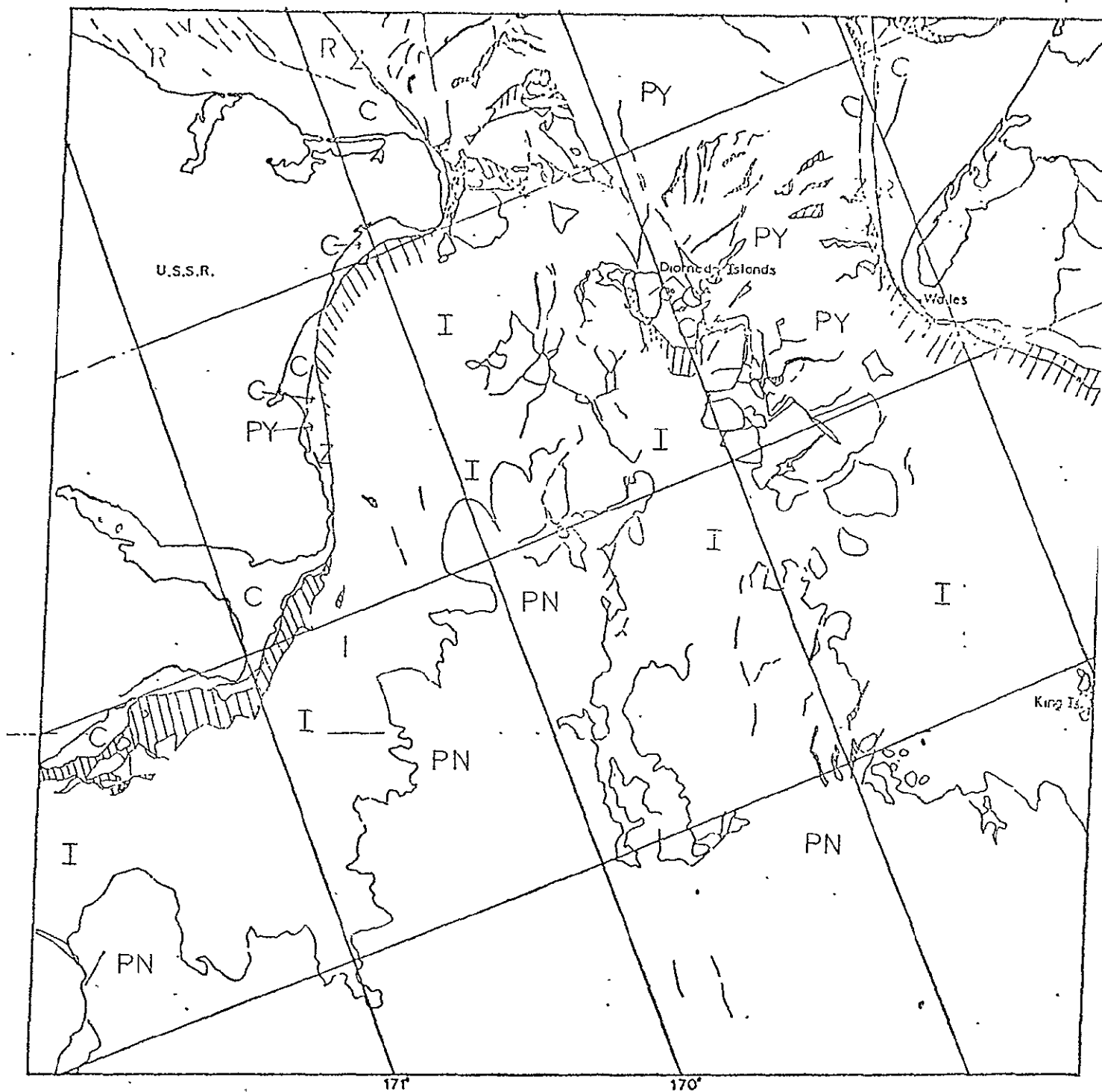
E-1227-22212-7  
 7 MARCH 1973



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

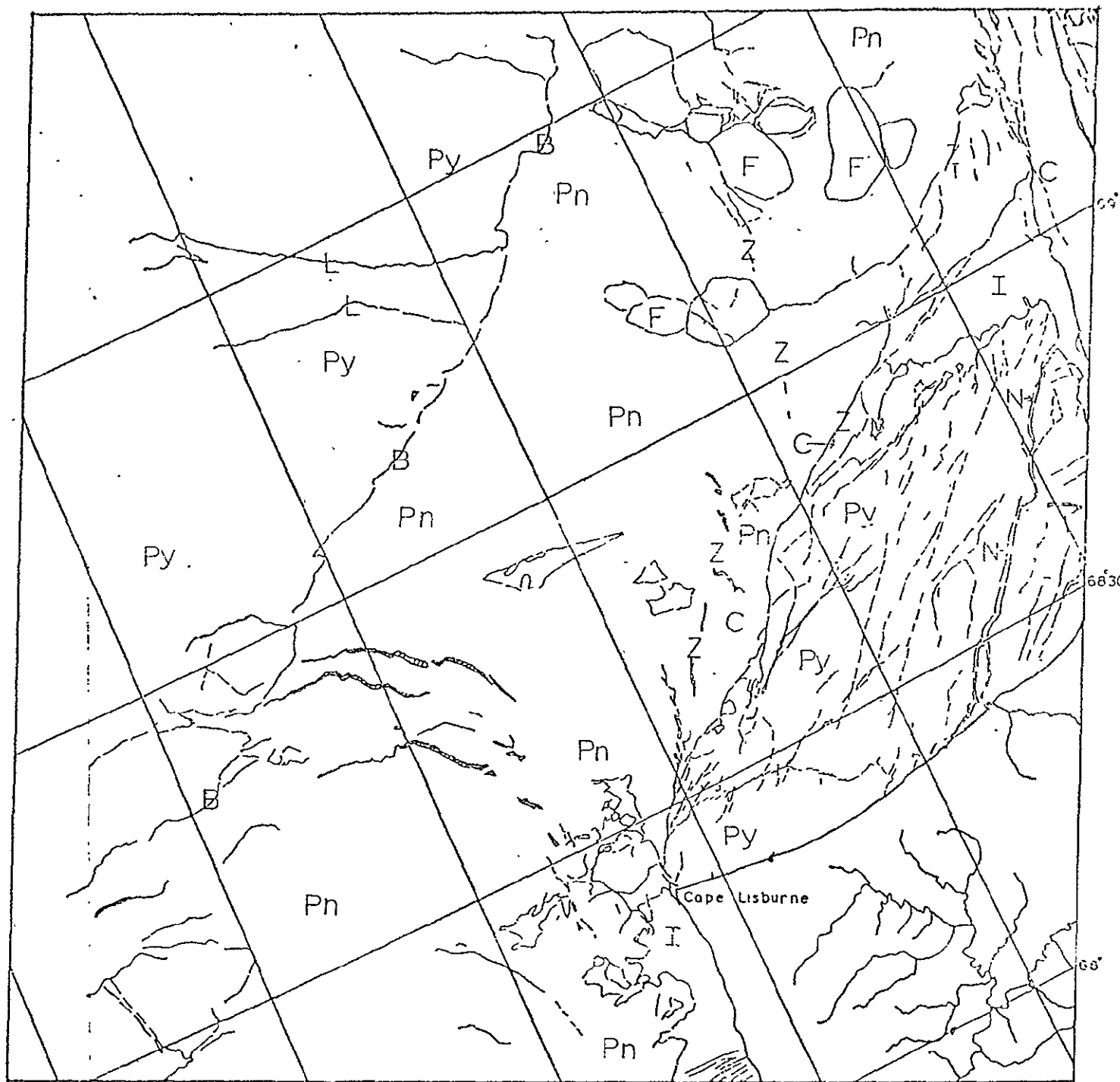
E-1227-22214-7  
7 MARCH 1973



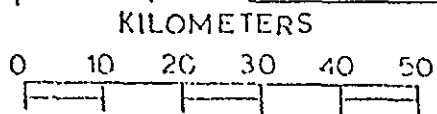
KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1227-22223-7  
7 MARCH 1973



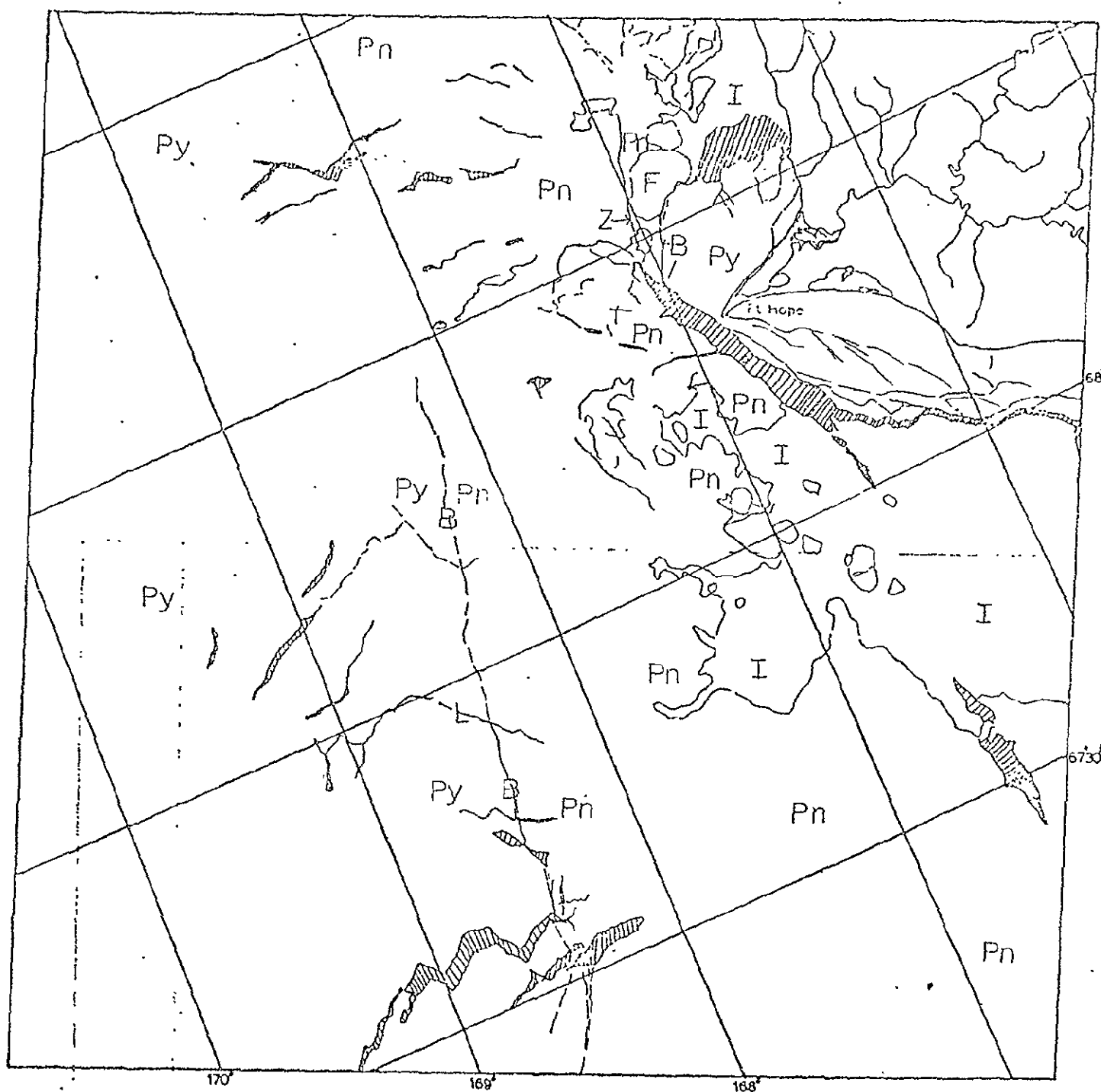
SYMBOLS	
	open water
	water crack
	refrozen crack
	shorefast ice or lead edge of ice
	pressure ridge
	ice flow
	grounded, if known
	hummock



E-1228-22270-7  
8 MARCH 1973

CHUKCHI SEA





KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1000,000

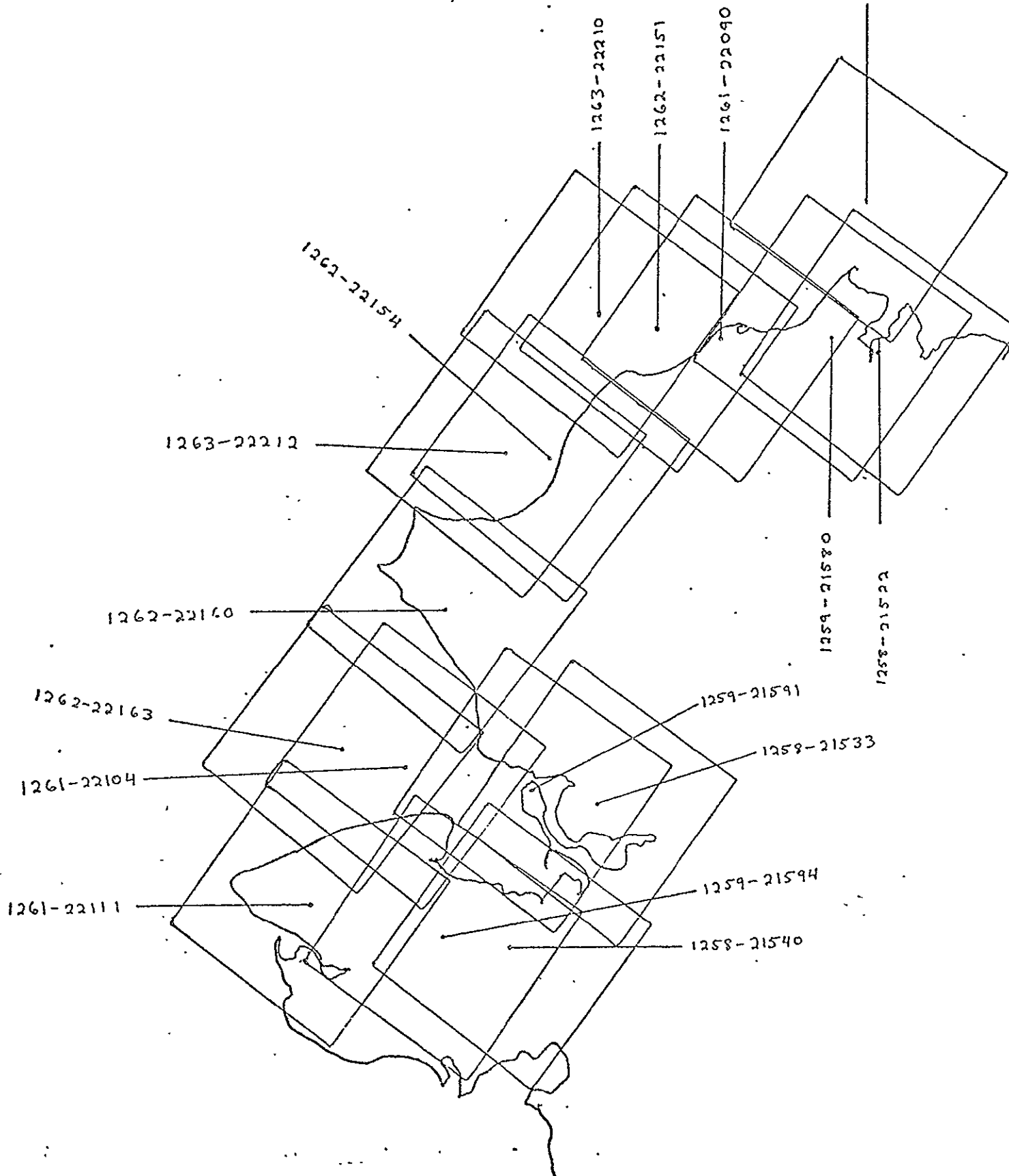
E-1228-92273-7  
 8 MARCH 1973

CHUKCHI SEA

# CHUKCHI SEA

7-24 APRIL 1973

Images 1258-1275

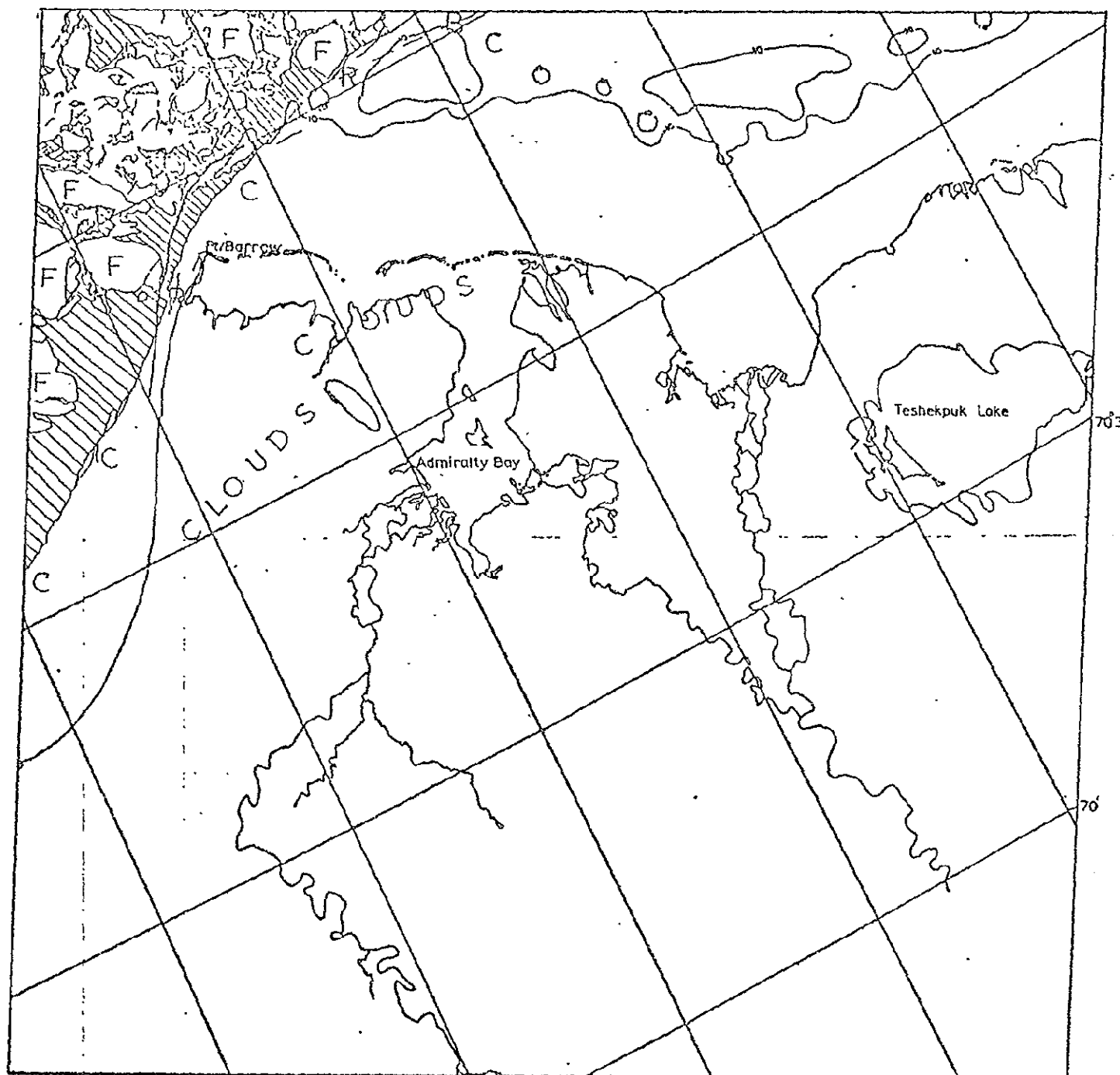


Scenes 1258-21522 } adjacent pair  
           1258-21533 }  
           1258-21540  
           1259-21580  
           1259-21591  
           1260-22032  
           1261-22090  
           1261-22104 } adjacent pair  
           1261-22111 }  
           1262-22151 } adjacent triplet  
           1262-22154 }  
           1262-22160 }  
           1263-22210 } adjacent pair  
           1263-22212 }

These scenes show the Chukchi coast between April 7-12, 1973. Kotzebue Sound is filled with contiguous ice out to a line between Cape Krusenstern and Cape Espenberg. A large lead has opened up along that line and down along the Espenberg Peninsula to the south.

At this time a relatively narrow band of fractured and mobile ice extending southward from Barrow along the coast. There is evidence along the coast in the form of polynyas on the south side of prominent features that this entire column of ice is moving southward. Although considerable amounts of contiguous ice have been mapped for this series few ridge systems were evident-partly because of thin clouds obscuring these details.

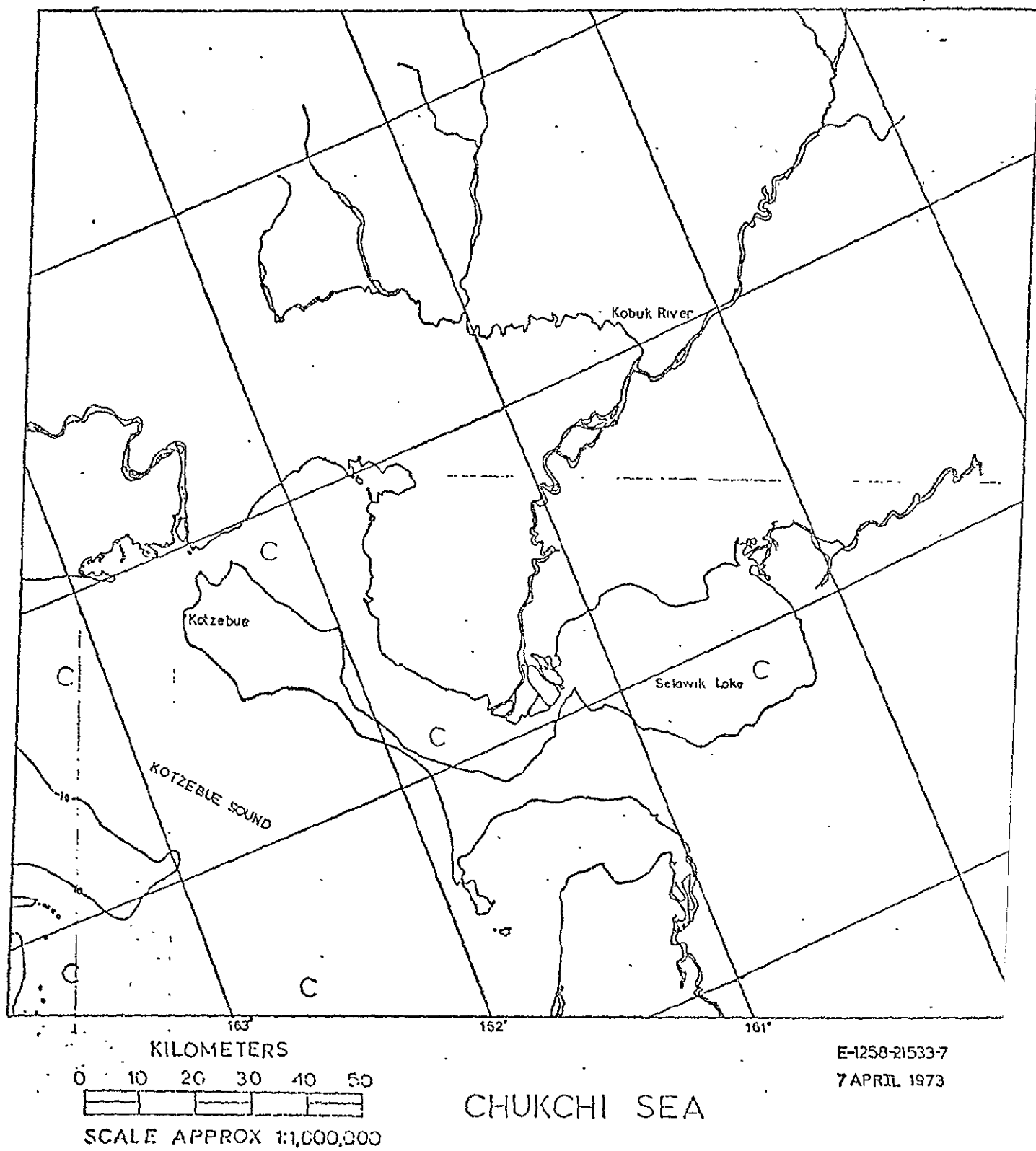
ORIGINAL PAGE IS  
 OF POOR QUALITY

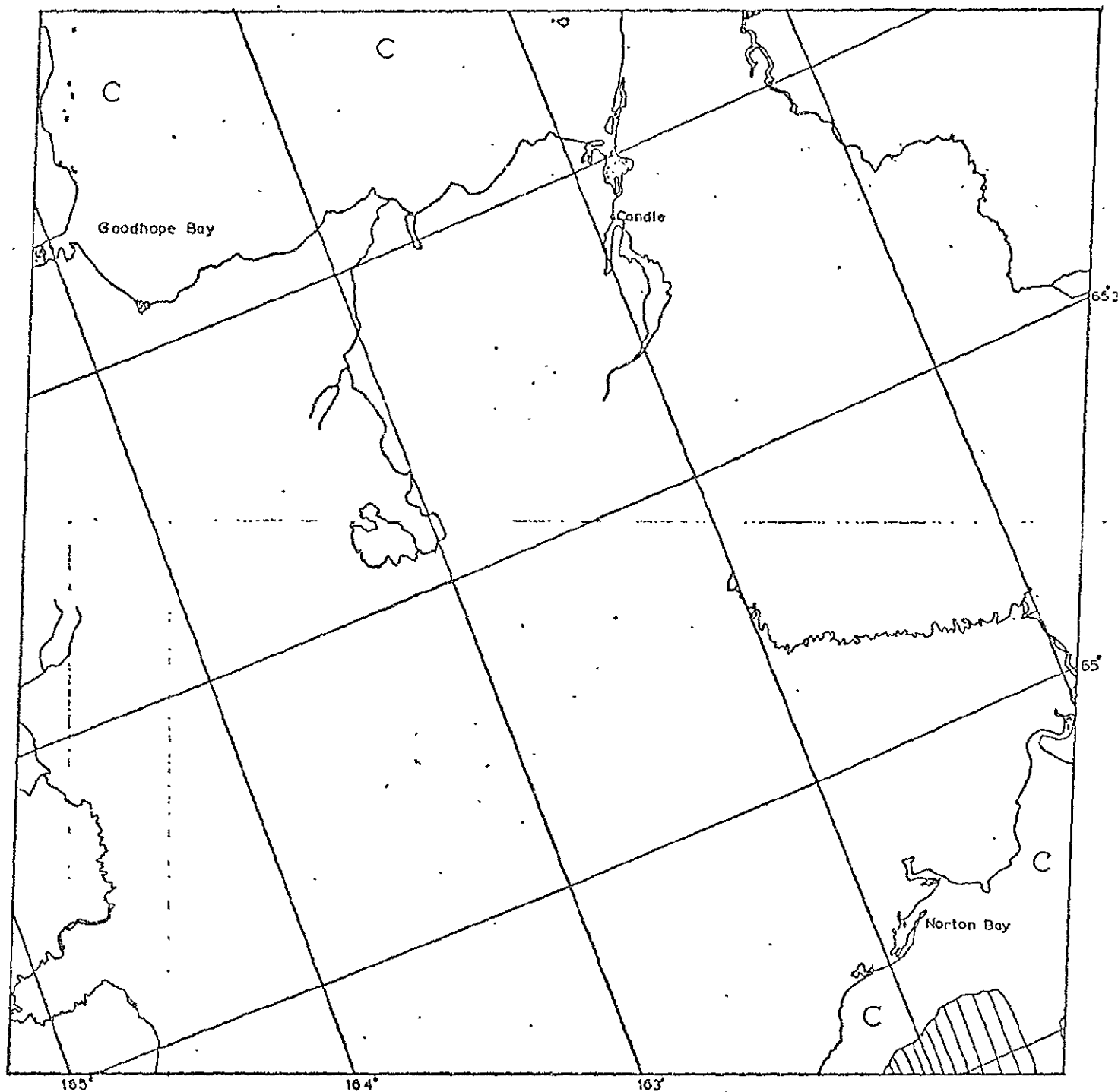


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

E-1258-21522-7  
 7 APRIL 1973

CHUKCHI SEA



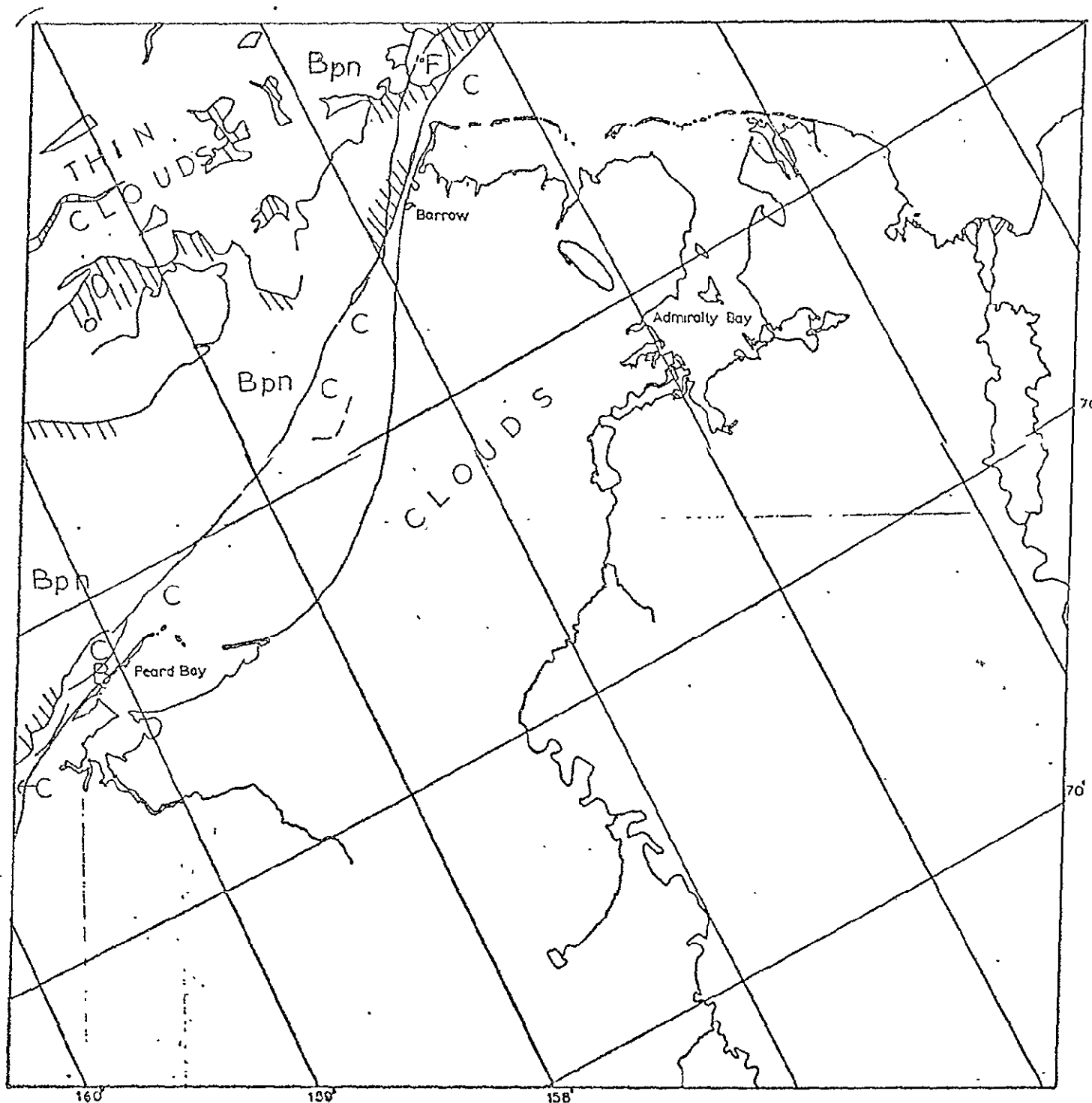


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1258-21540-7  
7 APRIL 1973

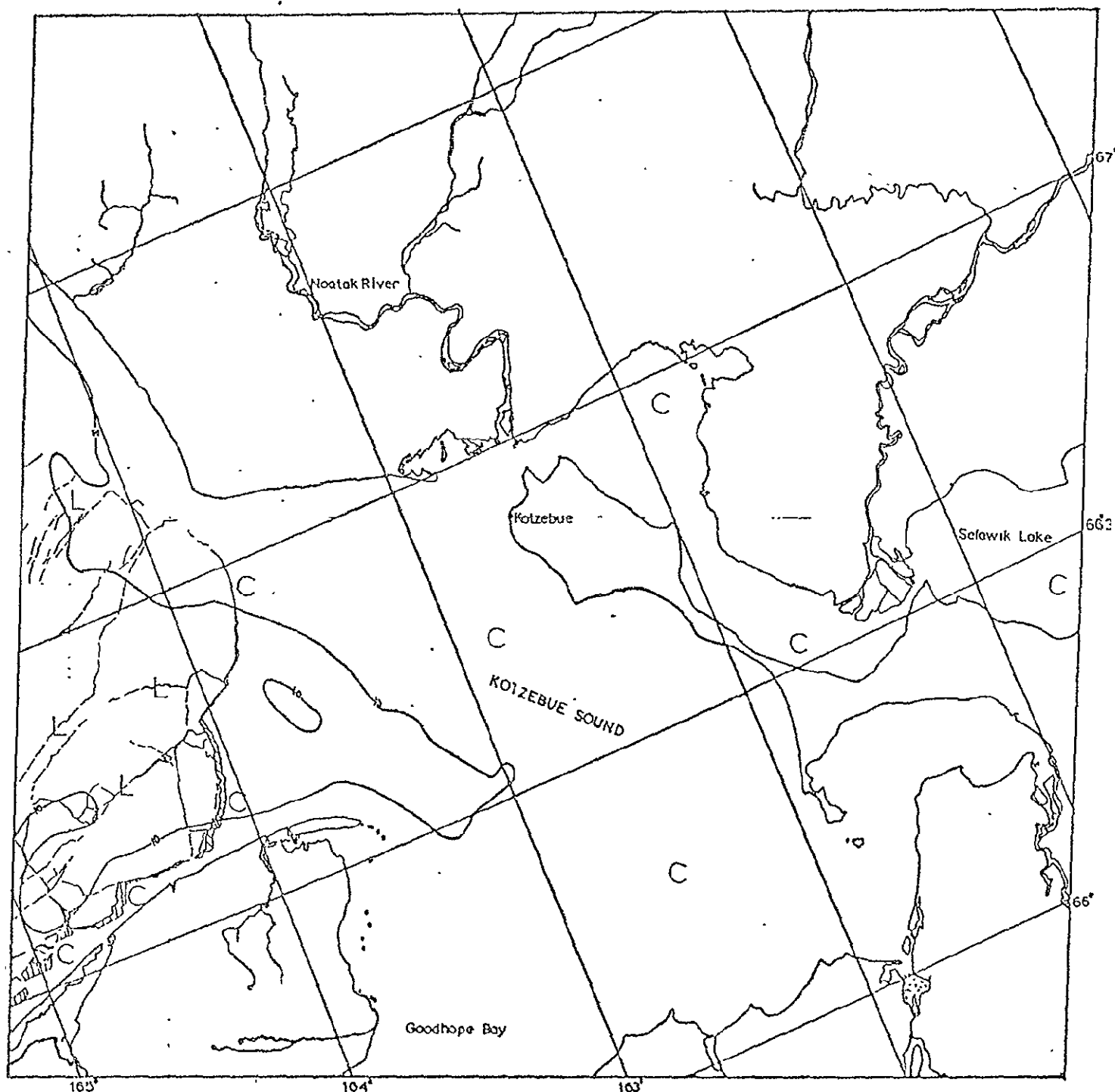
102



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1000000

E-1259-21580-7  
 8 APRIL 1973

CHUKCHI SEA

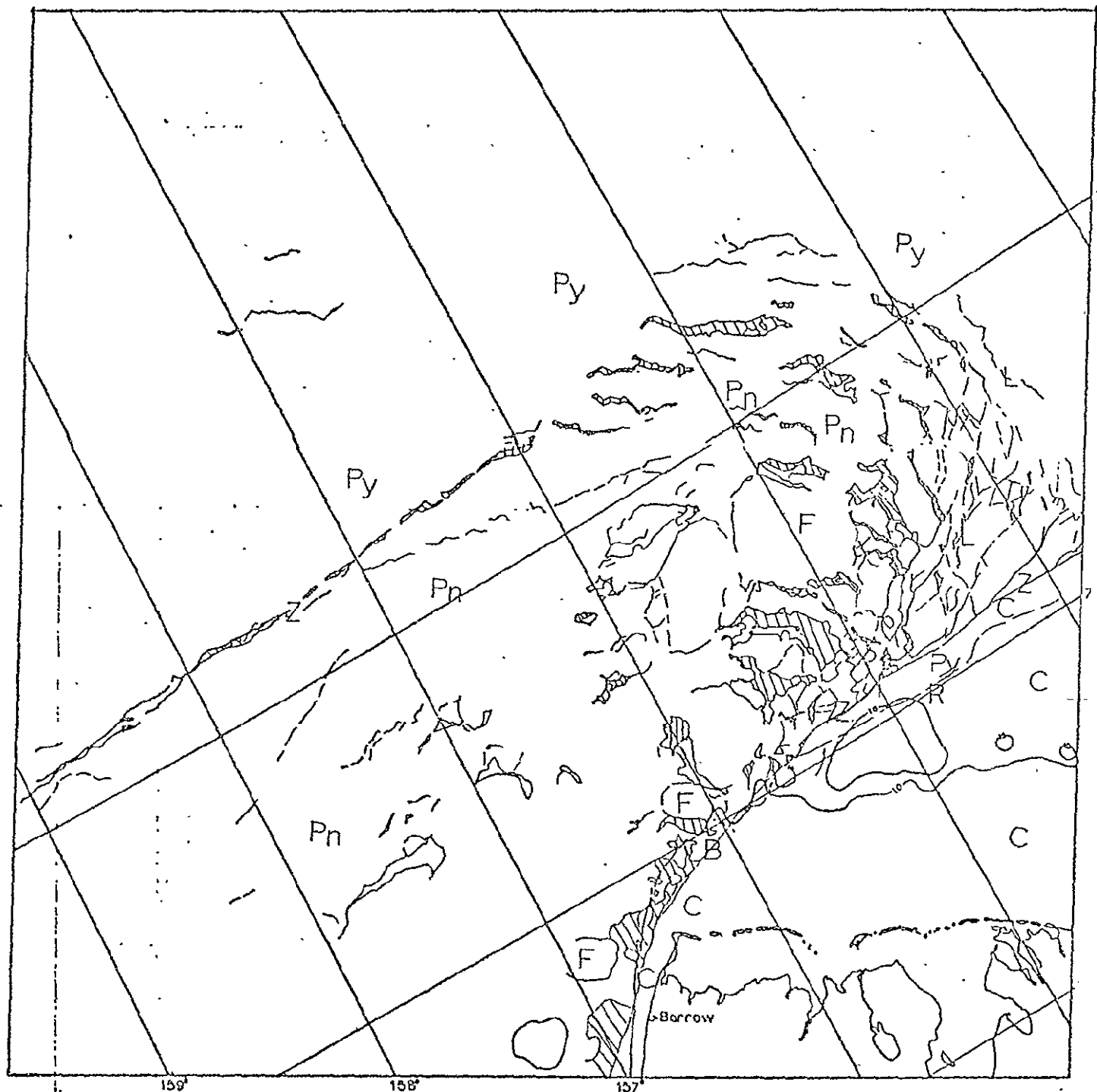


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

E-1259-21591-7  
 8 APRIL 1973

CHUKCHI SEA



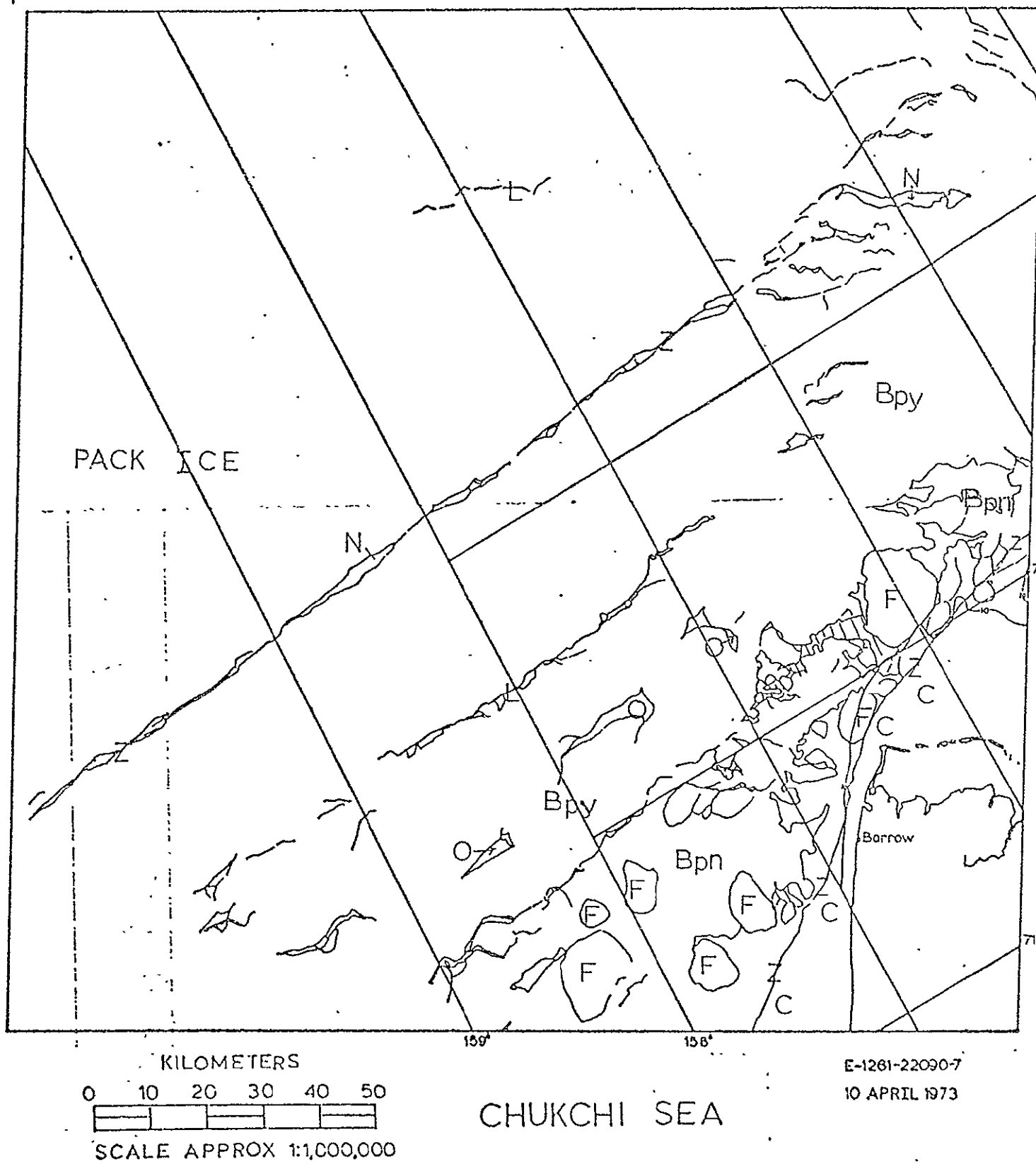


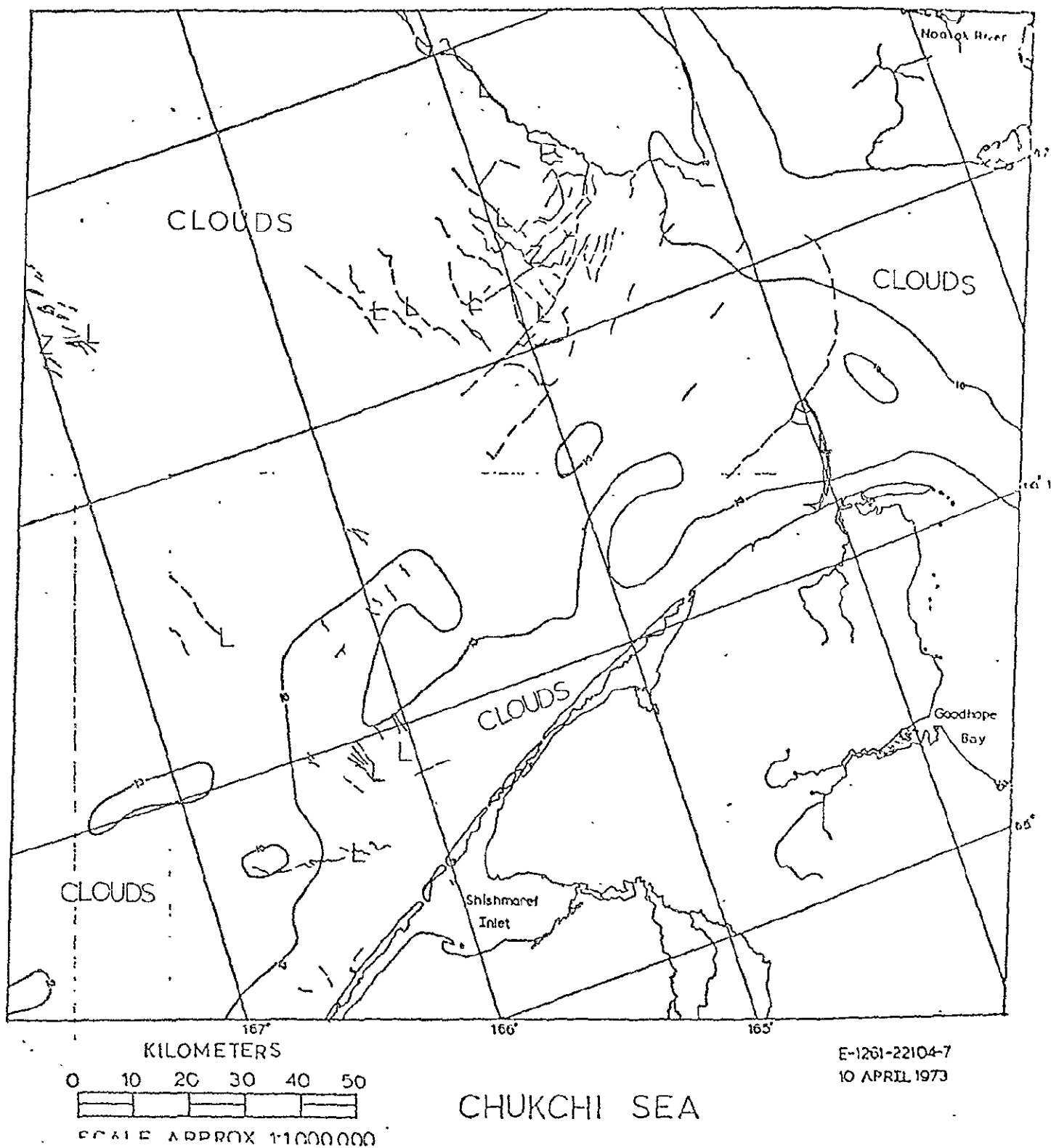
KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

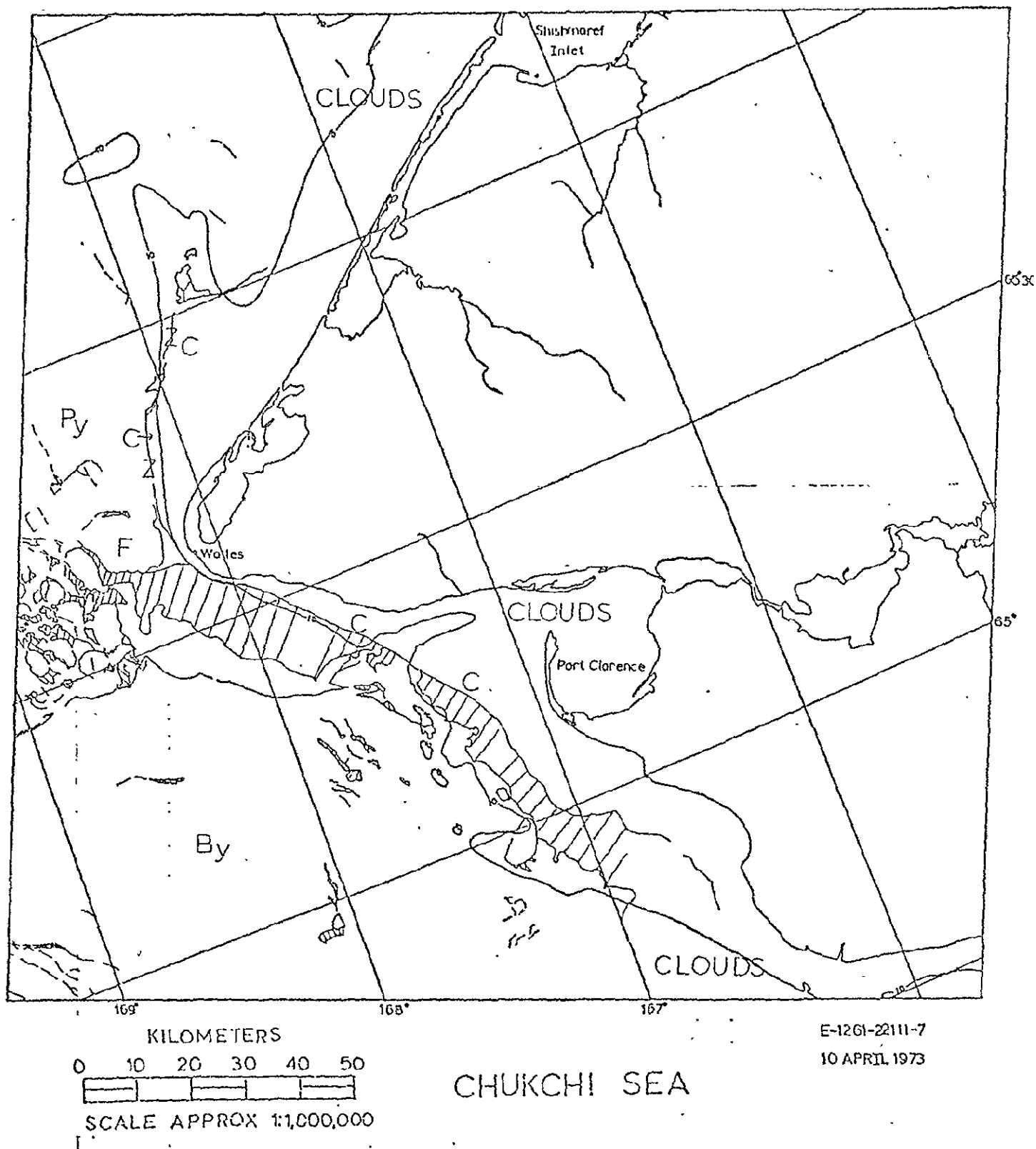
CHUKCHI SEA

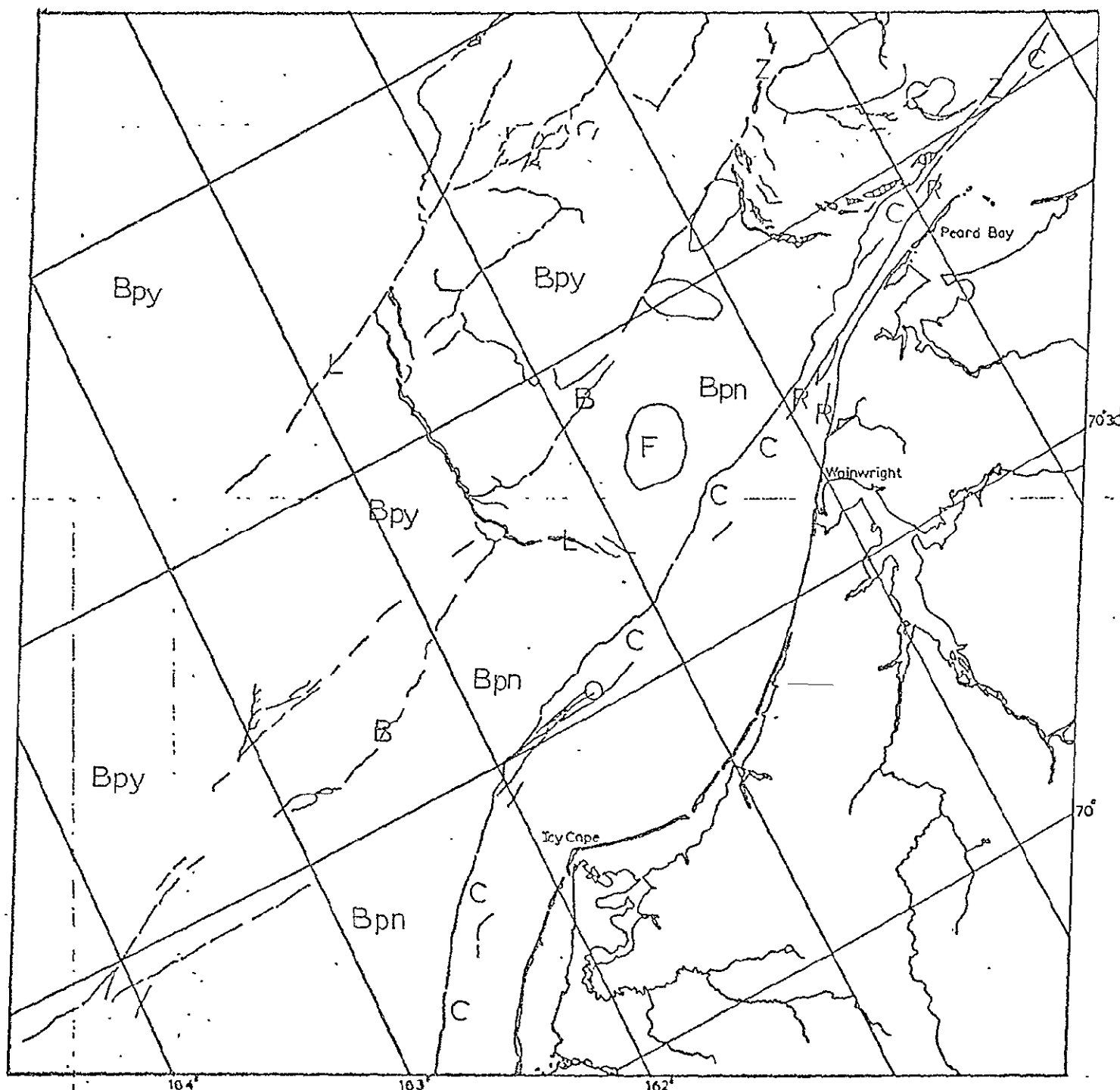
E-1260-22032-7

9 APRIL 1973





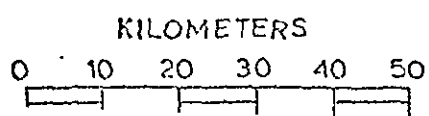
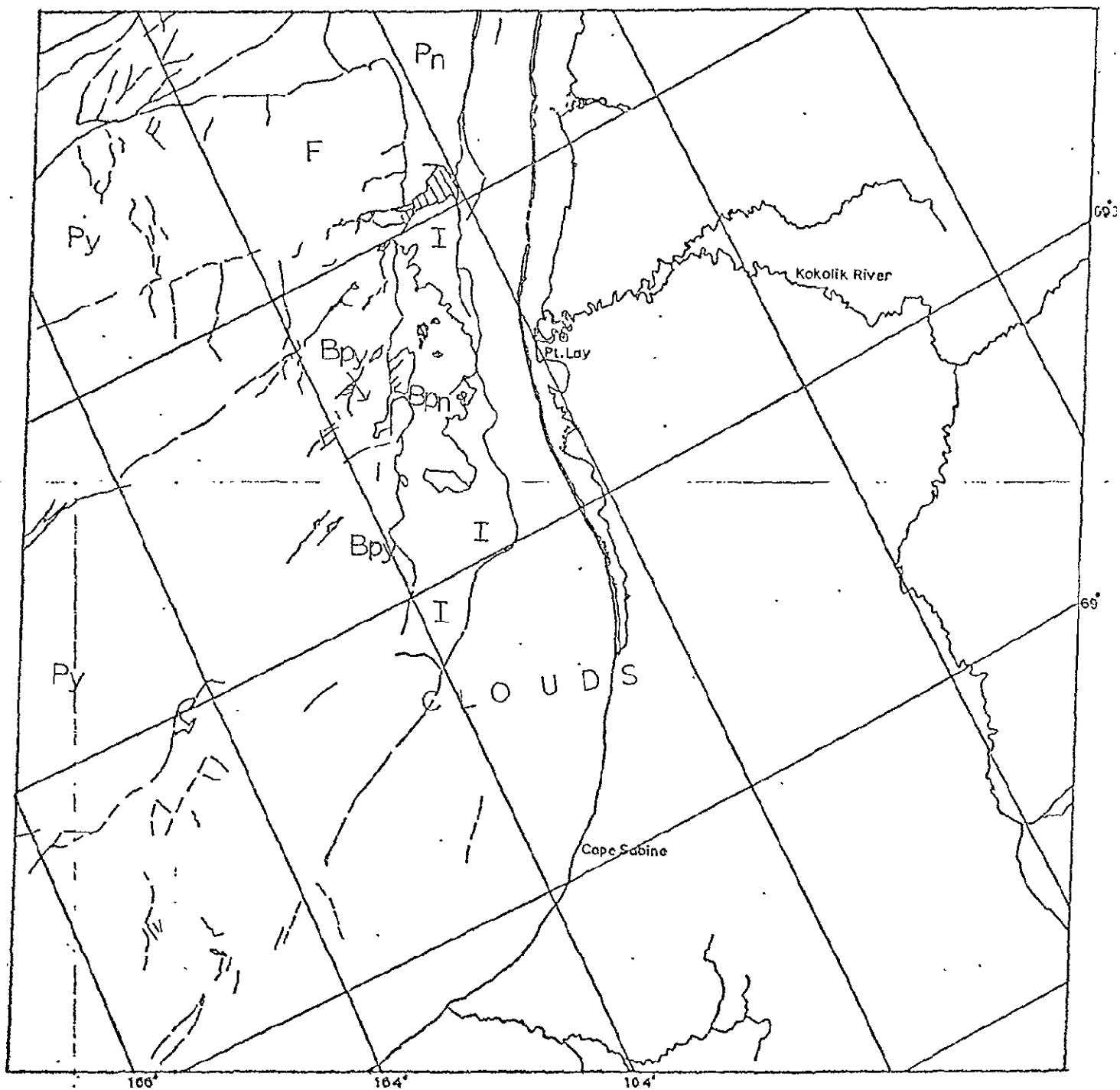




KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

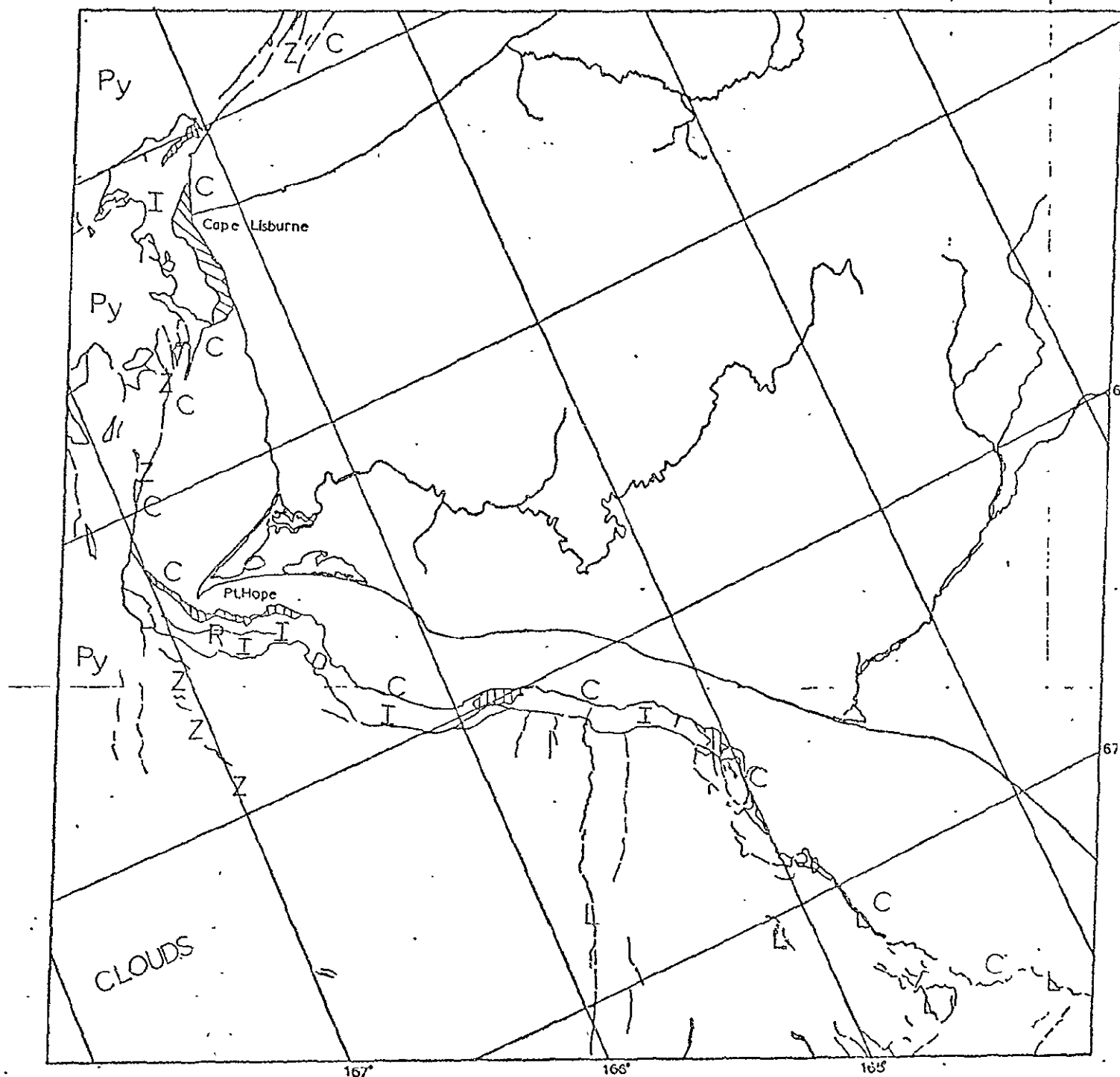
E-1262-22151-7  
11 APRIL 1973

CHUKCHI SEA



CHUKCHI SEA

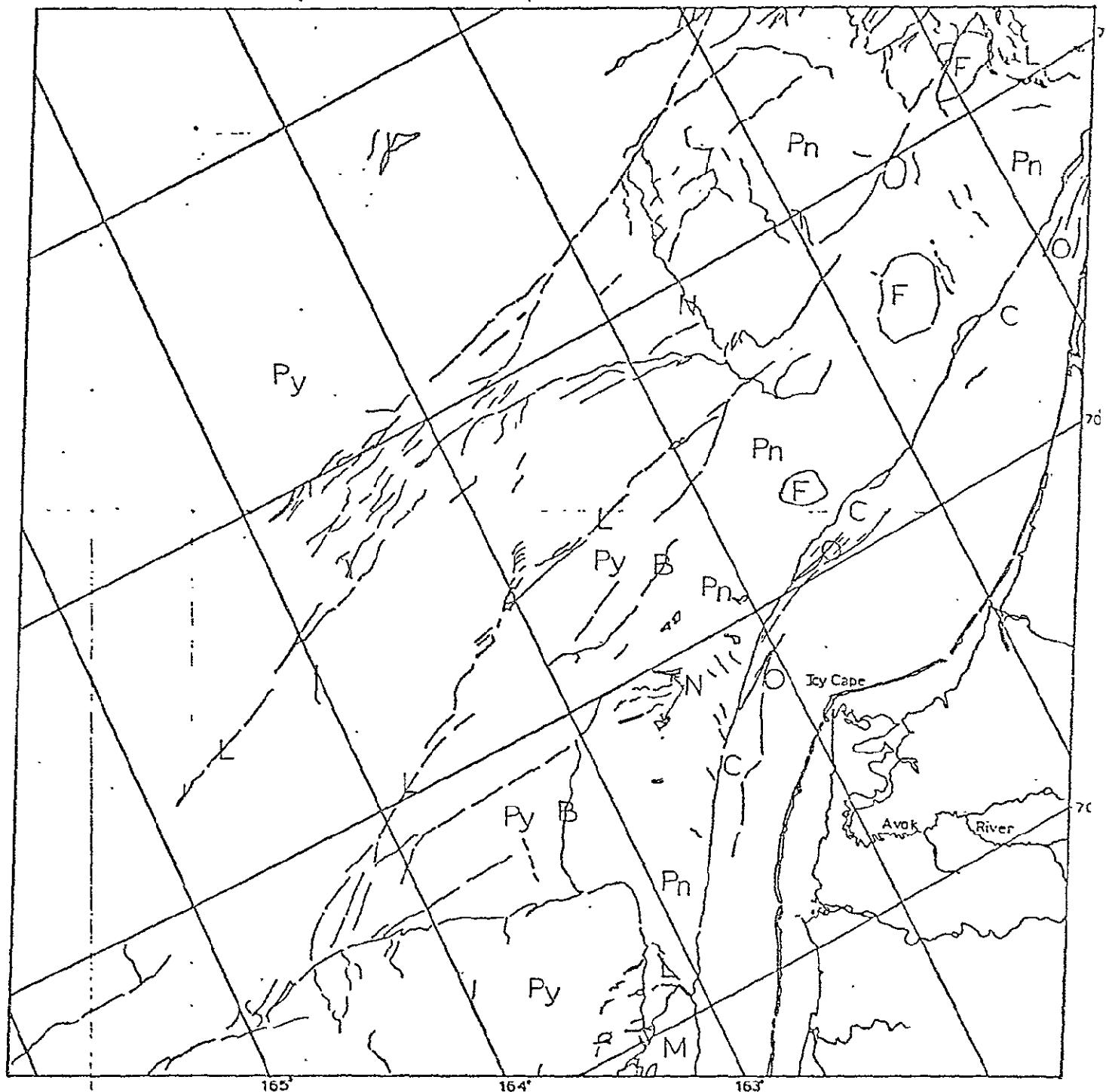
E-1262-22154-7  
11 APRIL 1973



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1262-22160-7  
11 APRIL 1973



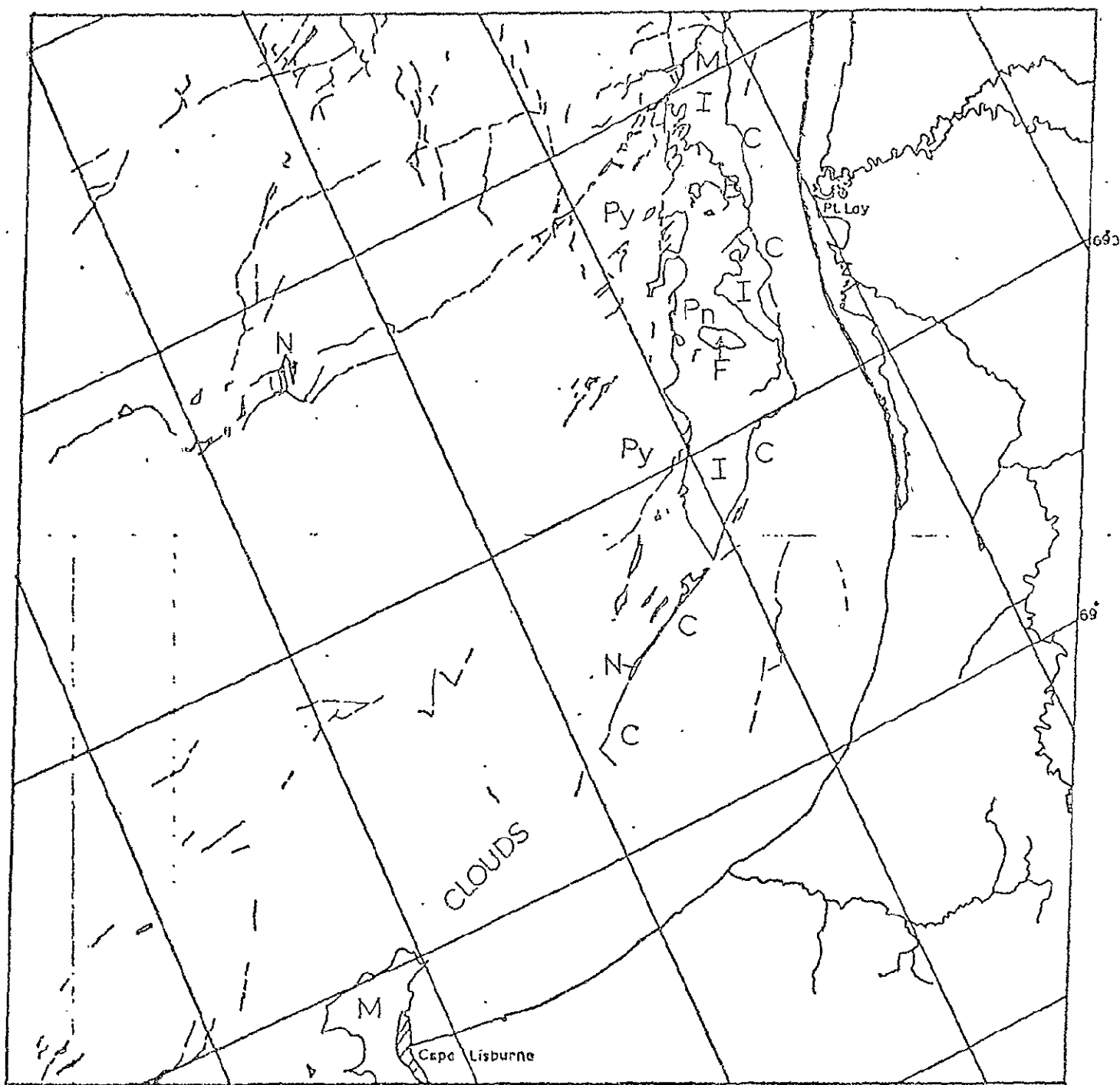
KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1263-22210-7  
 12 APRIL 1973

112





KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

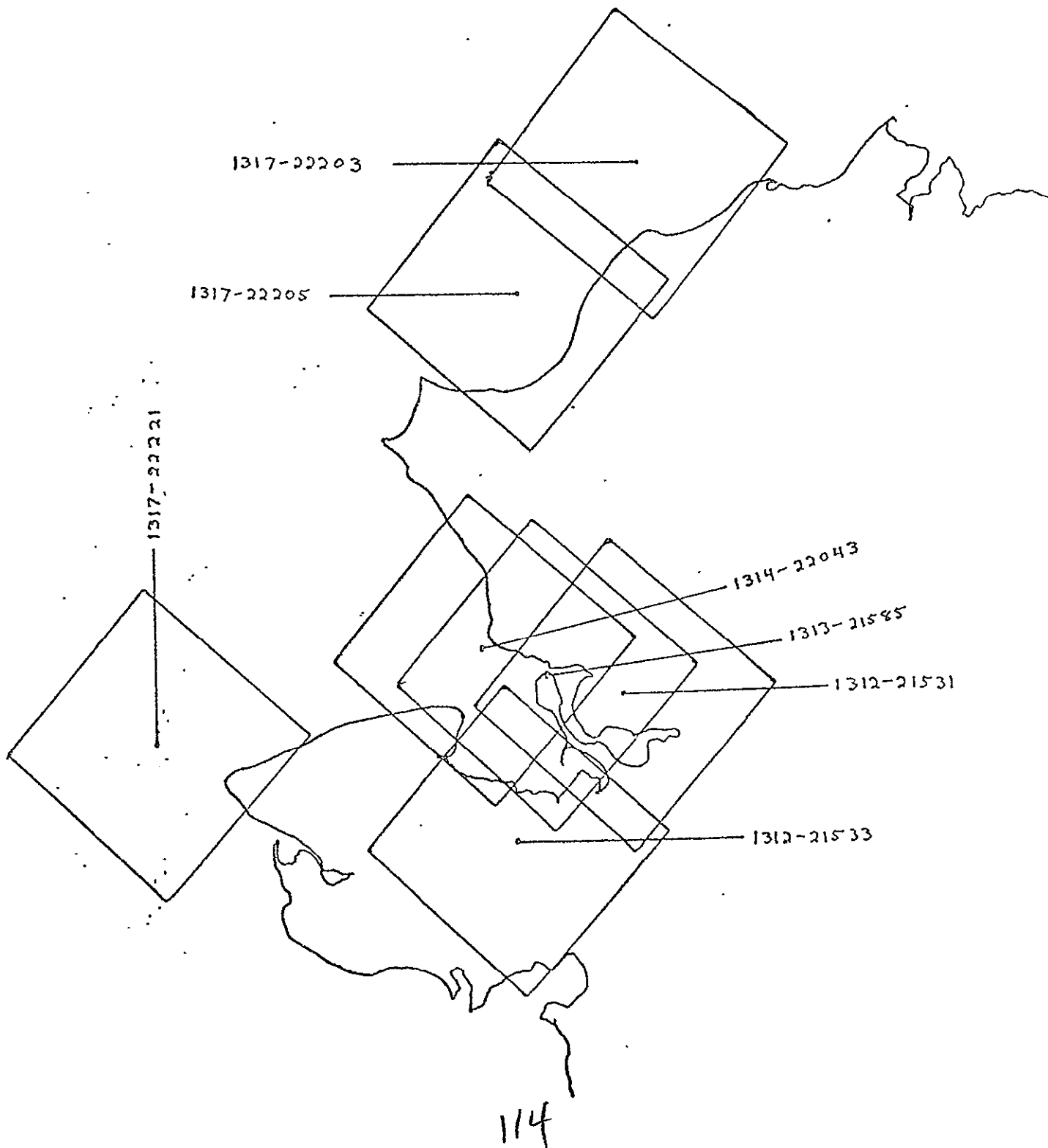
CHUKCHI SEA

E-1263-22212-7  
12 APRIL 1973

# CHUKCHI SEA

31 MAY-17 JUNE 1973

Images 1312-1329

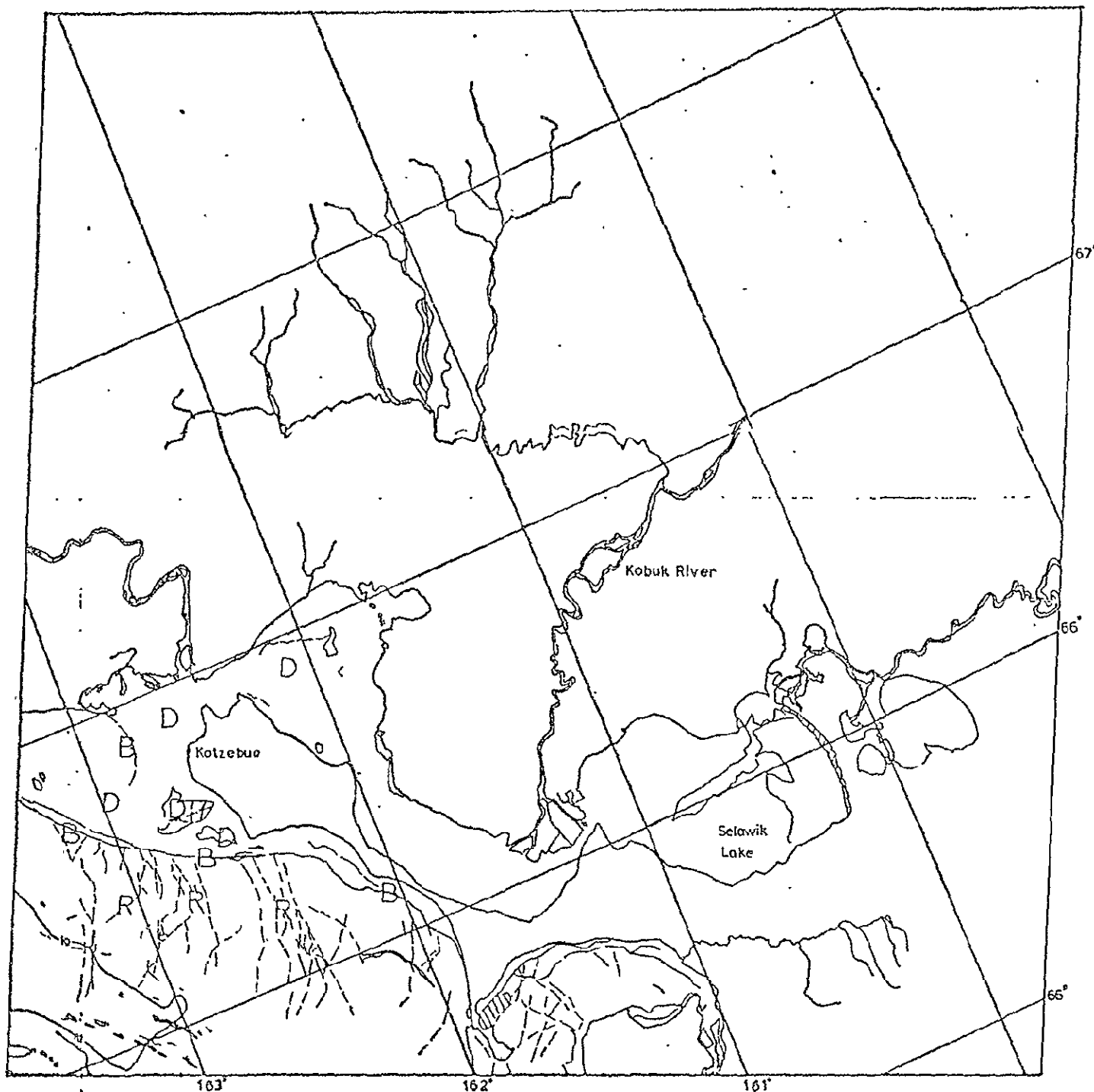


Scenes 1312-21531 } adjacent pair  
1312-21533 }  
1313-21585  
1314-22043  
1316-22153  
1317-22203 } adjacent pair  
1317-22205 }  
1317-2221

These scenes show the Kotzebue Sound, Point Lay and Bering Strait portions of the Chukchi coast between May 31 and June 5, 1973. This series of scenes shows near shore ice features formed during the previous winter. Many small ridges have been mapped in the Kotzebue sound region. These include an extensive ridge system which extends along the Baldwin Peninsula NW to Cape Krusenstern. To the south, the last remaining contiguous ice along the Espenberg indicates the probable extent of grounded ice.

To the north, in the Point Lay-Icy Cape area there are also extensive regions of remaining contiguous ice. Considerable grounded ice remains on Blossom Shoals. Farther to the south, where massive ridging did not occur, it appears that in the absence of these protective features, the near shore apron has been considerably eroded.

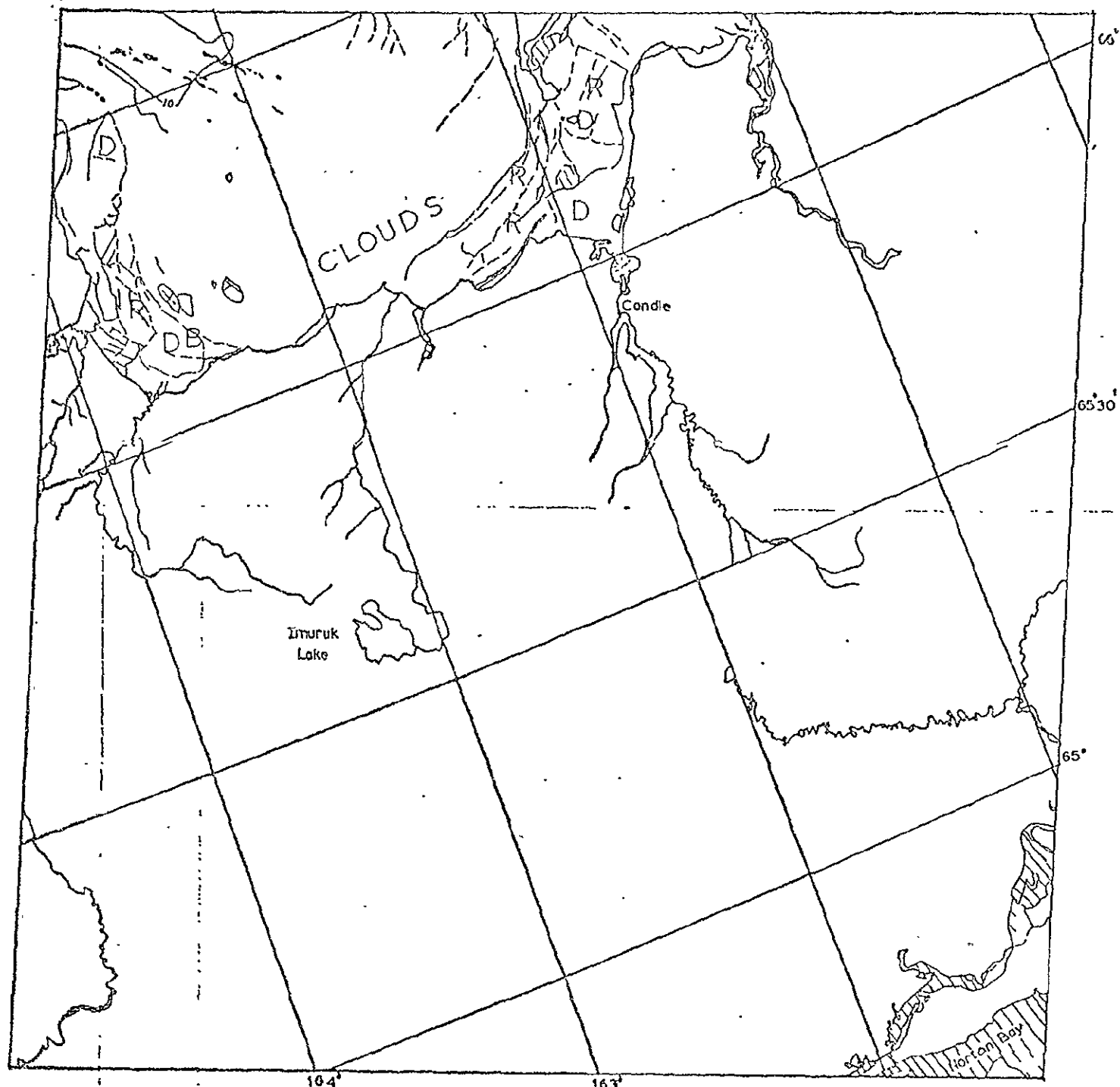
ORIGINAL PAGE IS  
OF POOR QUALITY



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

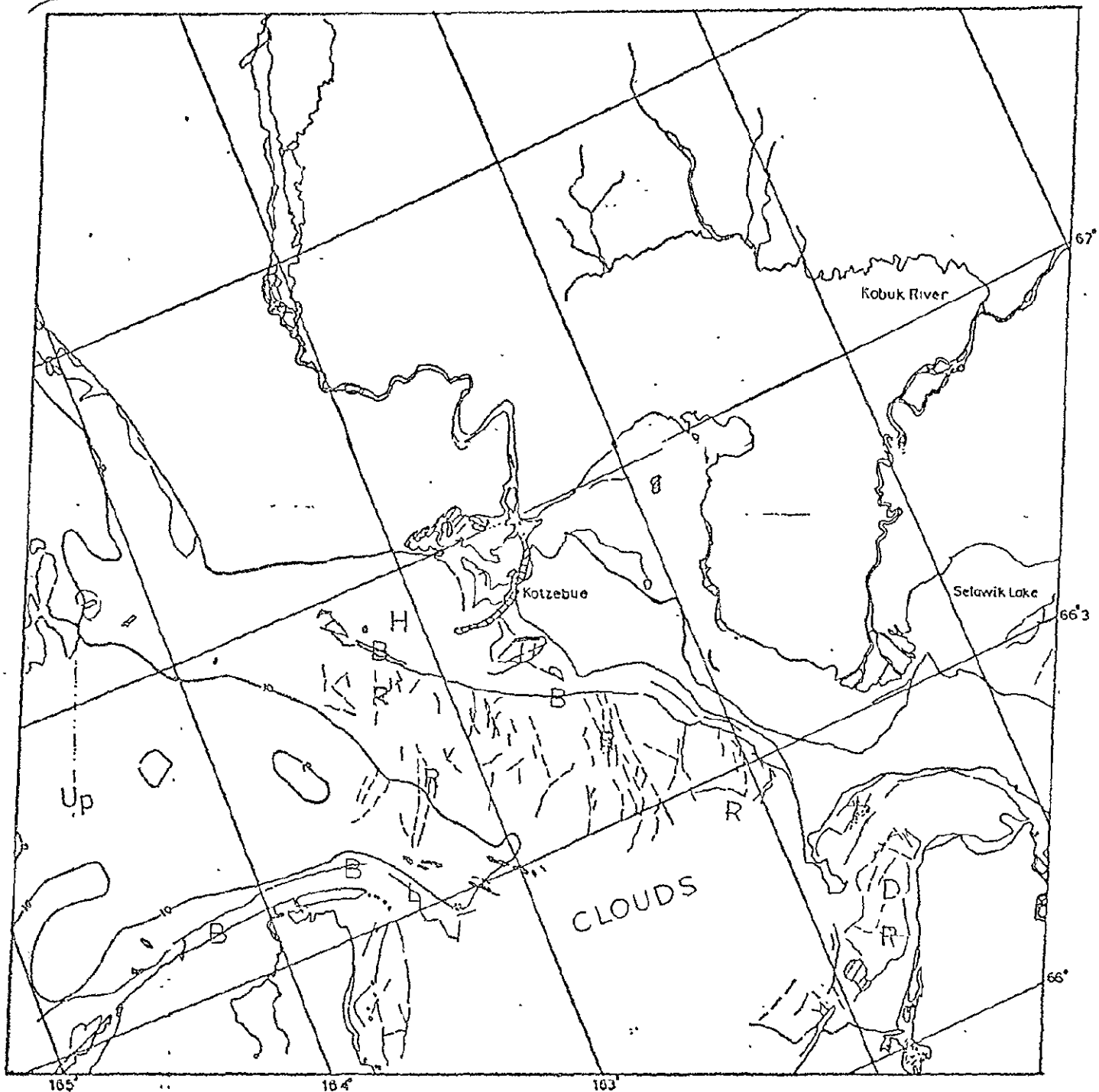
E-1312-21531-7  
 31 MAY 1973



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

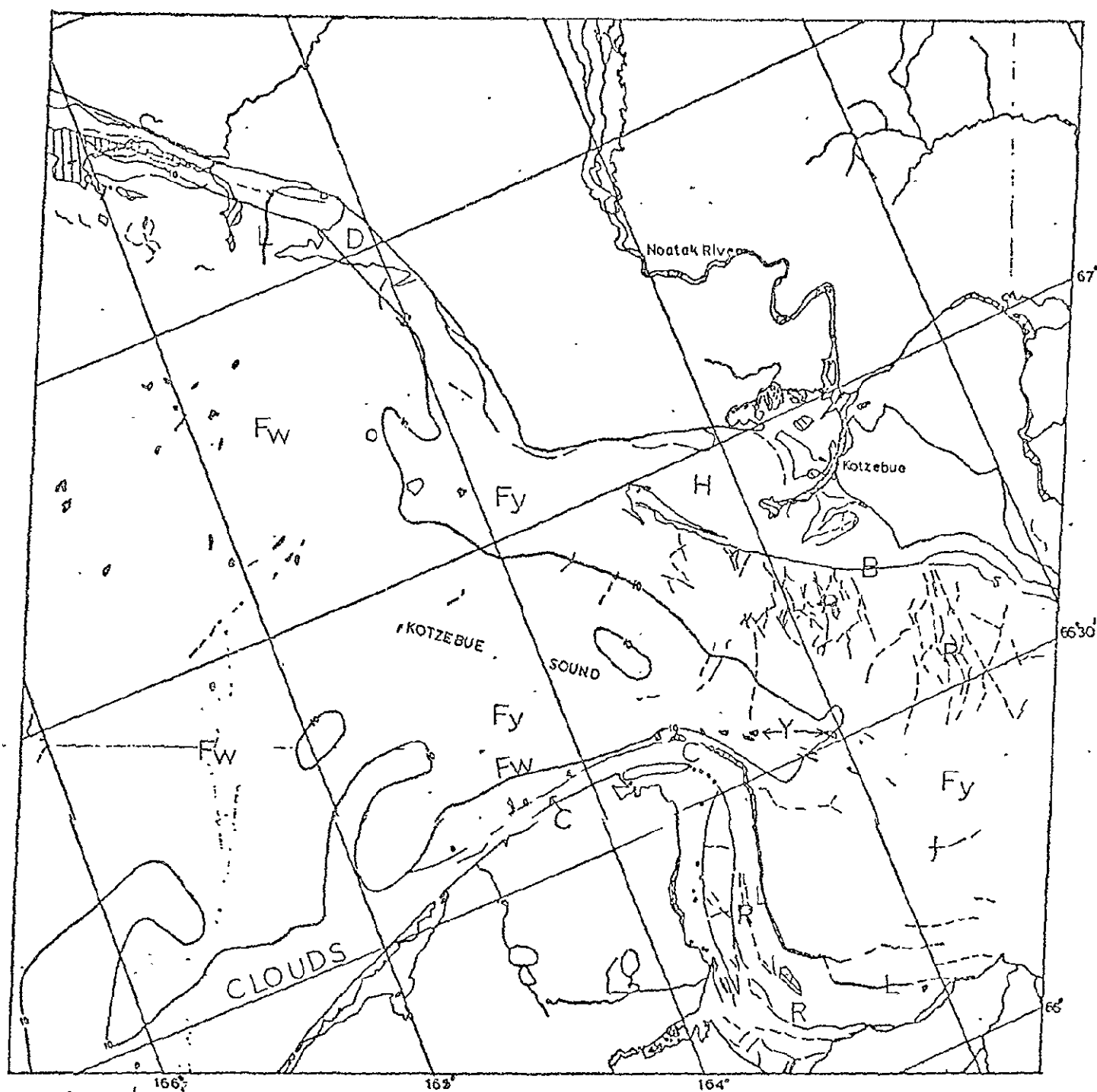
E-1312-21533-7  
 31 MAY 1973



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

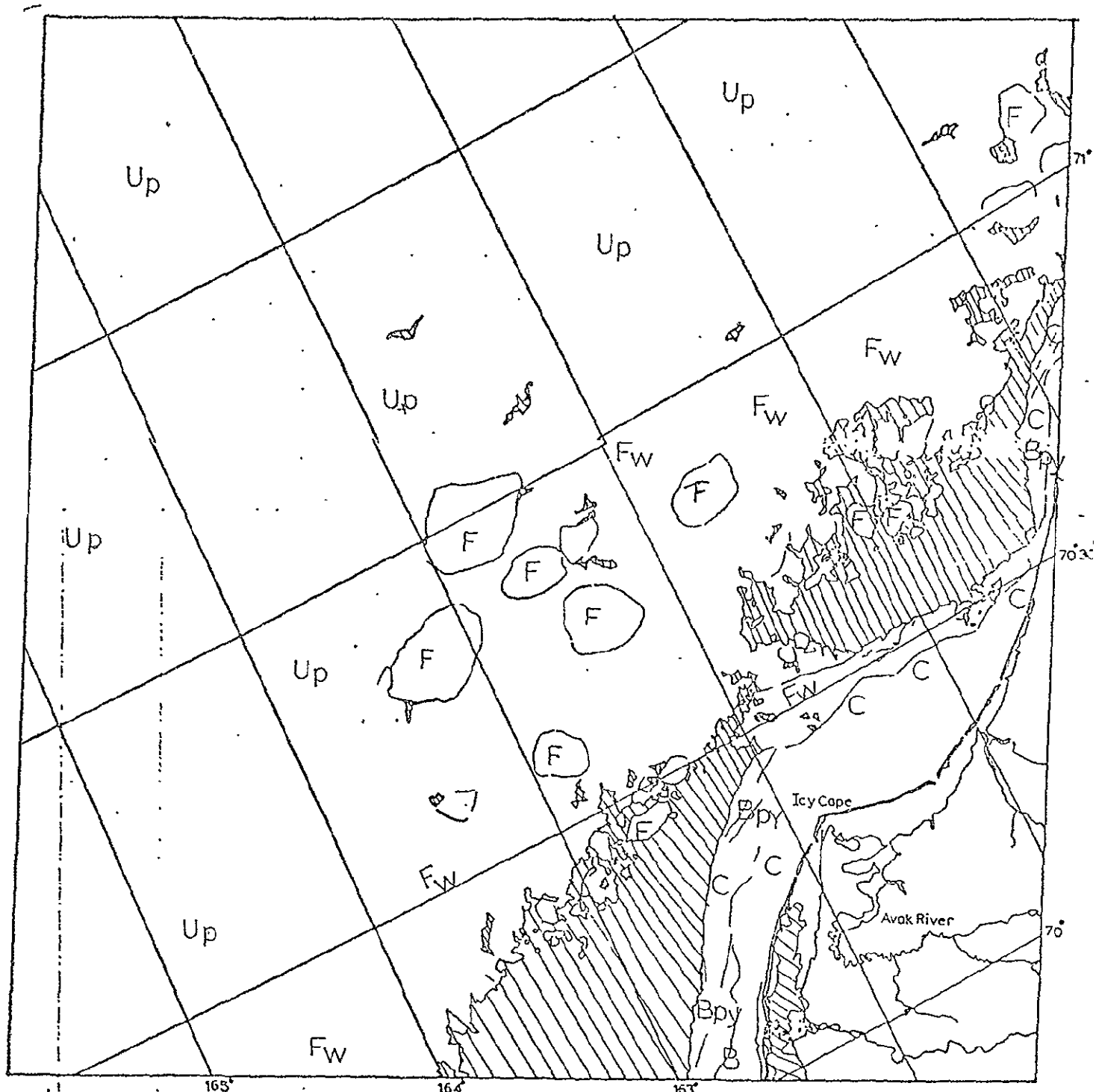
E-1313-21585-7  
1 JUNE 1973



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1314-22043-7  
2 JUNE 1973



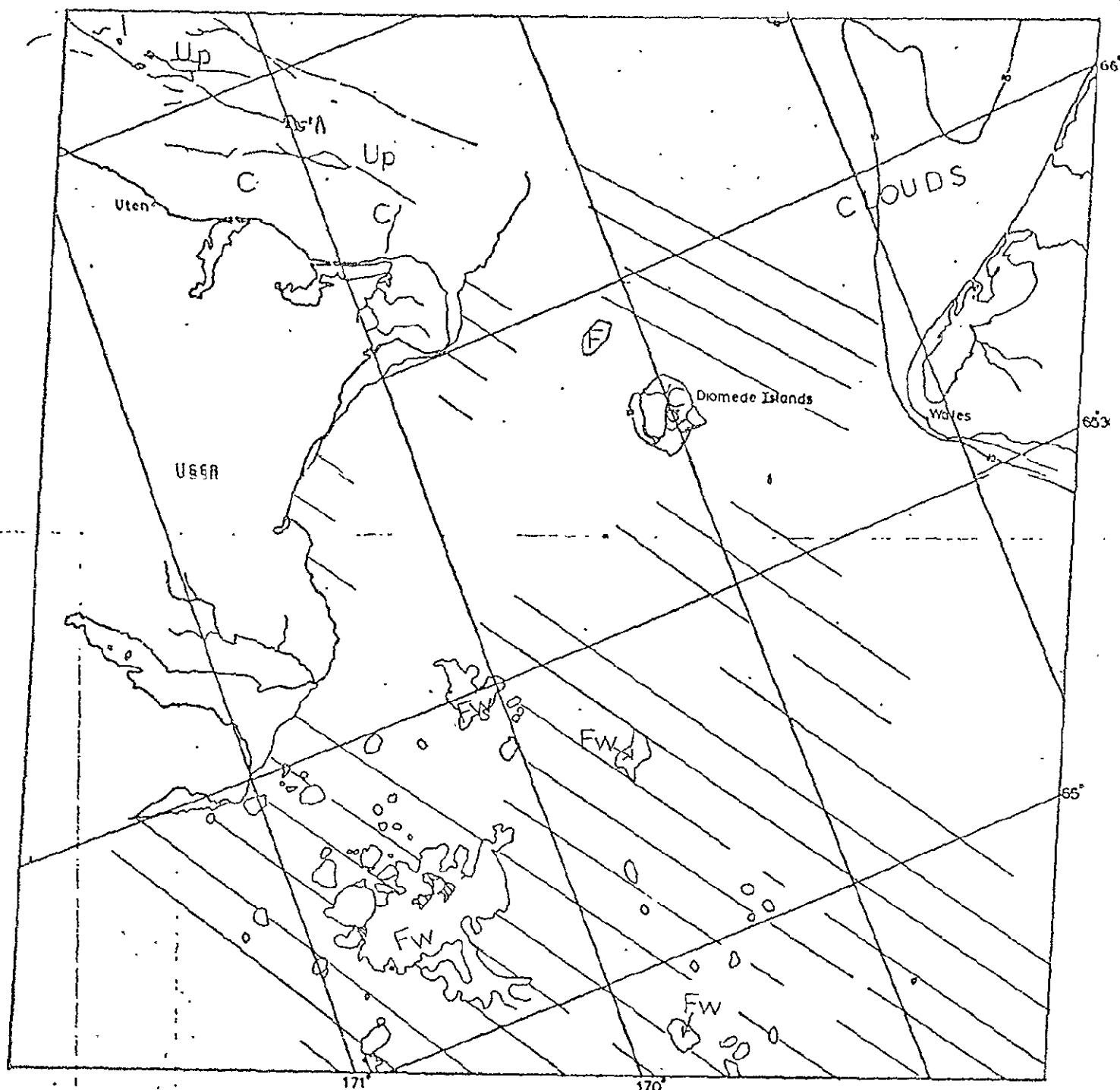
KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

E-1317-22203-7  
5 JUNE 1973

CHUKCHI SEA







KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

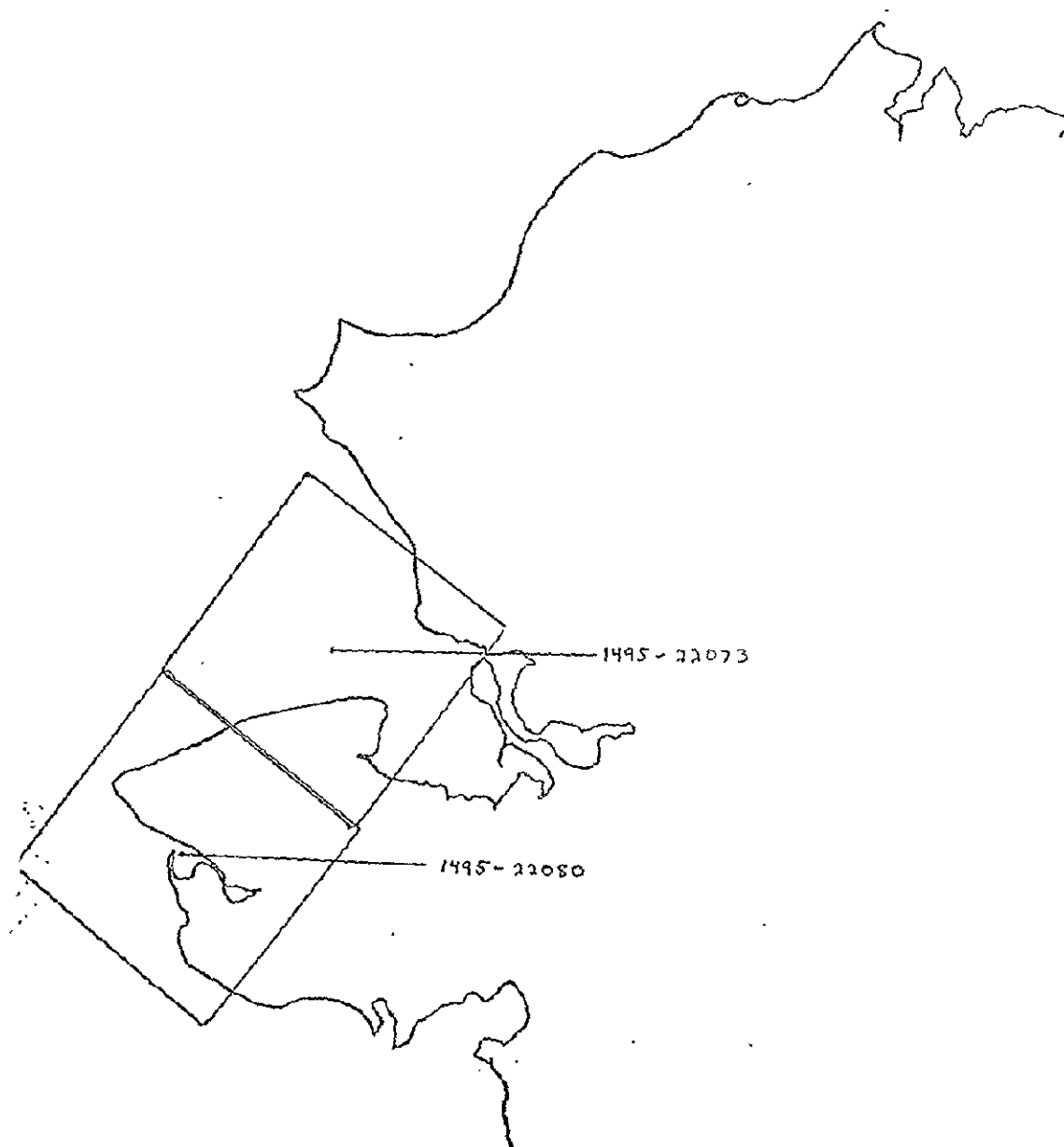
E-1317-22221-7  
 5 JUNE 1973

CHUKCHI SEA

# CHUKCHI SEA

27 NOVEMBER-14 DECEMBER  
1973

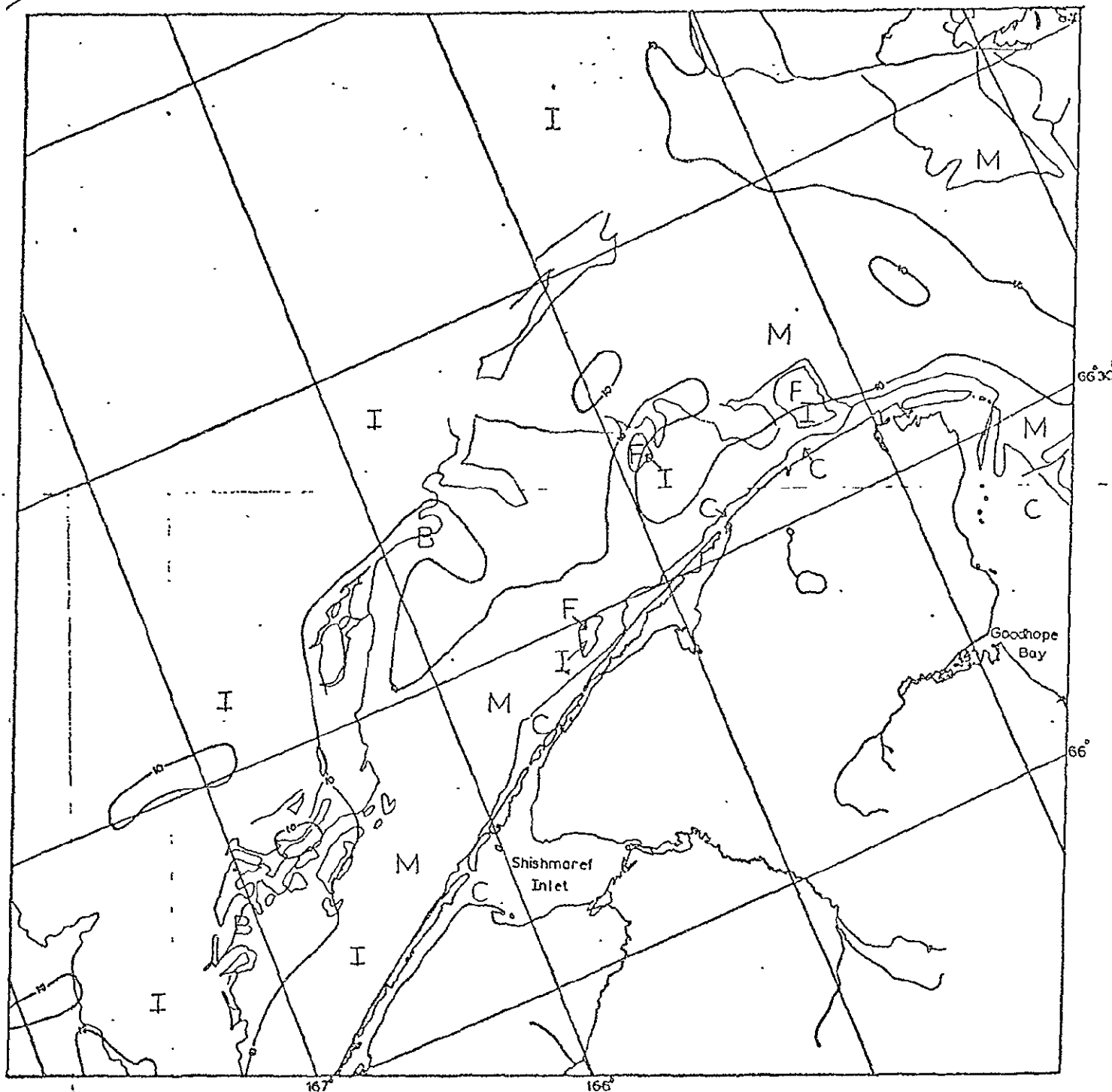
Images 1492-1509



Scenes 1495-22080

1495-22073

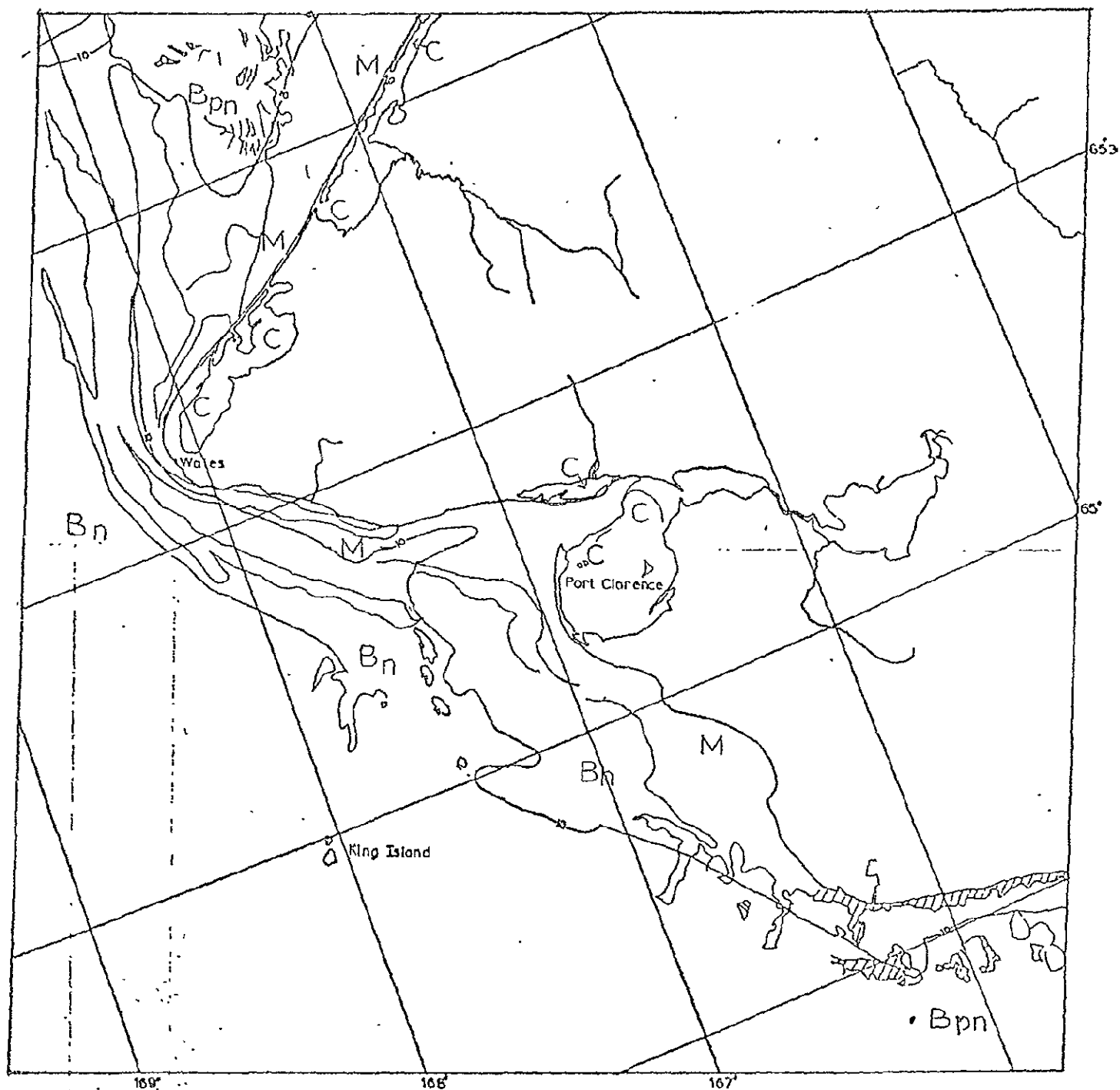
These two scenes show the Cape Prince of Wales area on November 30, 1973. The solar elevation angle at the time of acquisition was one degree. At this time the oceanic ice consists of new to young ice. Along the coast a thin irregular ribbon of contiguous ice can be found adjacent to the shore.



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1495-22073-7  
30 NOV. 1973



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

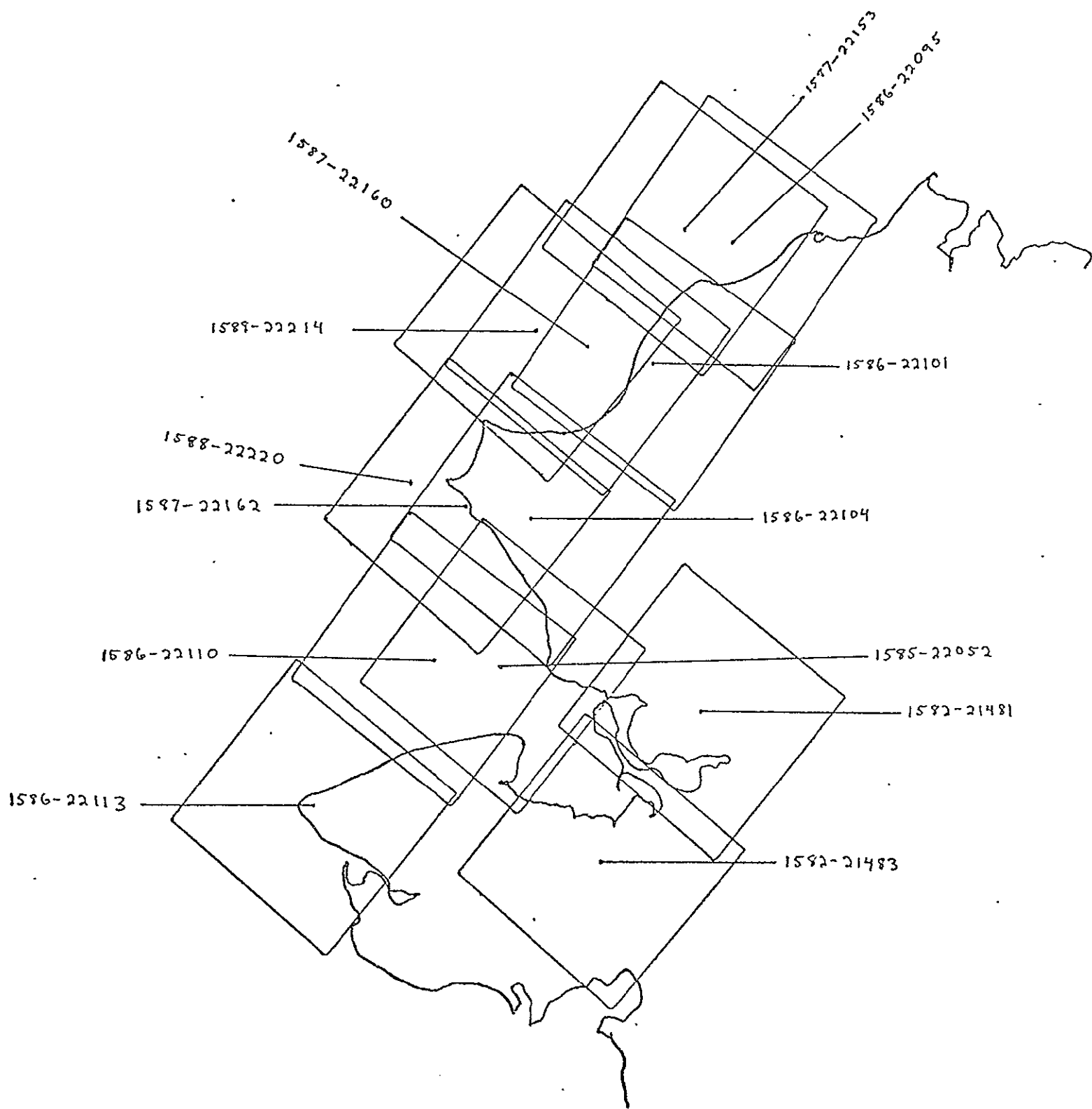
CHUKCHI SEA

E-1495-22030-7  
 30 NOV. 1973.

# CHUKCHI SEA

25 FEBRUARY-14 MARCH  
1974

Cycle 1582-1599



Scenes 1582-21481 } adjacent pair  
 1582-21483 }  
 1582-22052  
 1586-22095 } adjacent pair  
 1586-22101 }  
 1586-22110 } adjacent pair  
 1586-22113 }  
 1587-22160 }  
 1587-22162 } adjacent triplet  
 1587-22153 }  
 1588-22214 } adjacent pair  
 1588-22220 }

These scenes show the portion of the Chukchi coast from Bering Strait to Point Franklin between February 25 and March 3, 1974. At this time Kotzebue Sound is covered with continuous first year ice out to a line well beyond the entrance to the sound. At that location a large lead has opened up in a large sweeping curve from south to north. This lead has frozen over to the late new ice stage at this time. However, to the west many new leads are opening up as part of a general system of ice motion to the northwest.

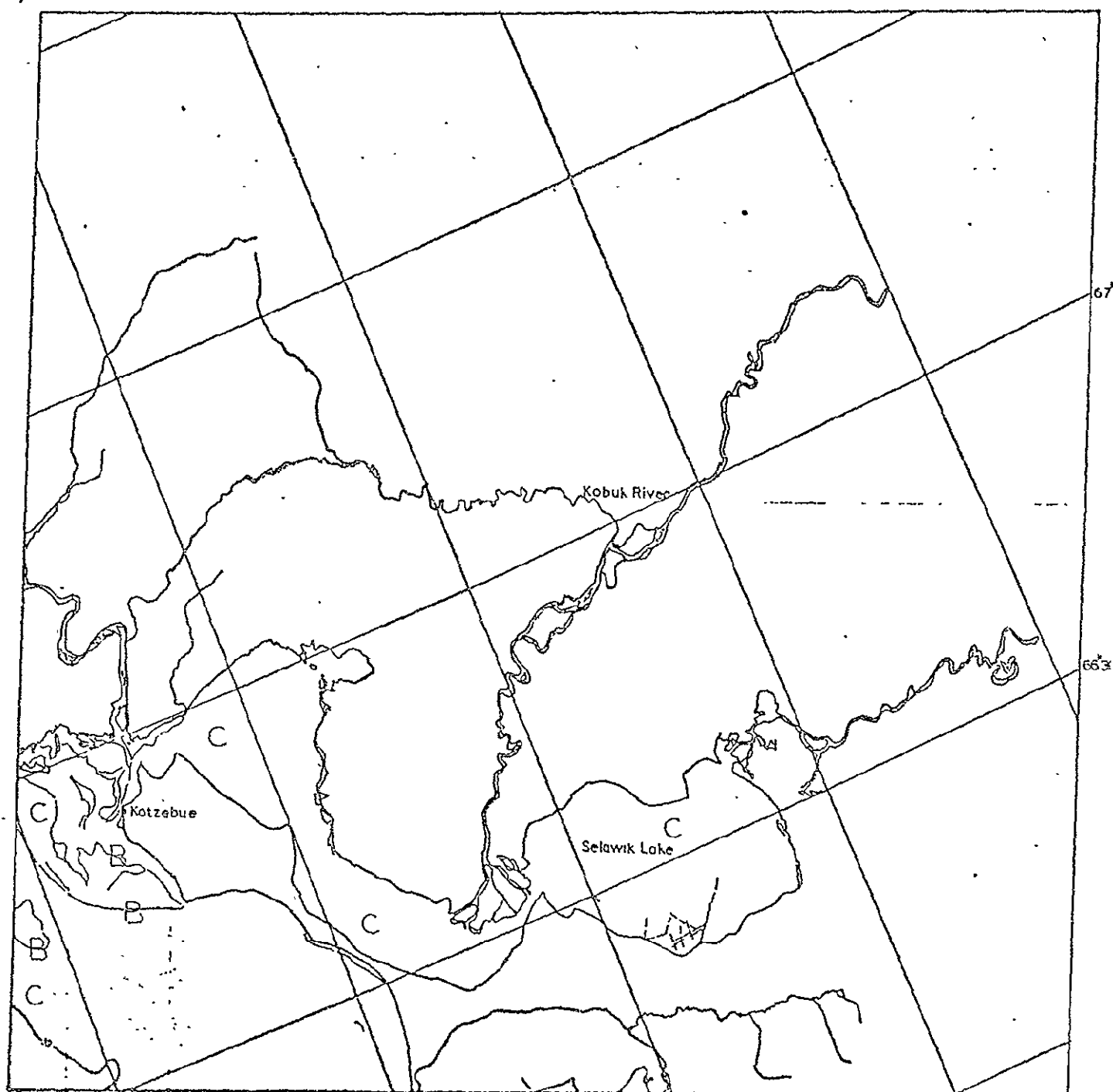
At Bering Strait there is evidence of ice motion northward through the strait. Long trails of new ice to the north of King Island and the Diomedes indicate that this motion has been taking place for some time.

To the north of Cape Prince of Wales there are two groups of extension shear ridge systems forming a narrow "V" pointed to the south. These ridge systems are very likely at least partly grounded on shoals in this area and form the western side of an extensive area of contiguous ice. At this time however, a lead has formed which is cutting off the western side of the "V"--indicating that its anchoring (if any) was not very great.

Farther to the north extensive ridging appears across Blossom Shoal and from Point Franklin southward along the coast to a point just south of Wainwright.

ORIGINAL PAGE IS  
 OF POOR QUALITY

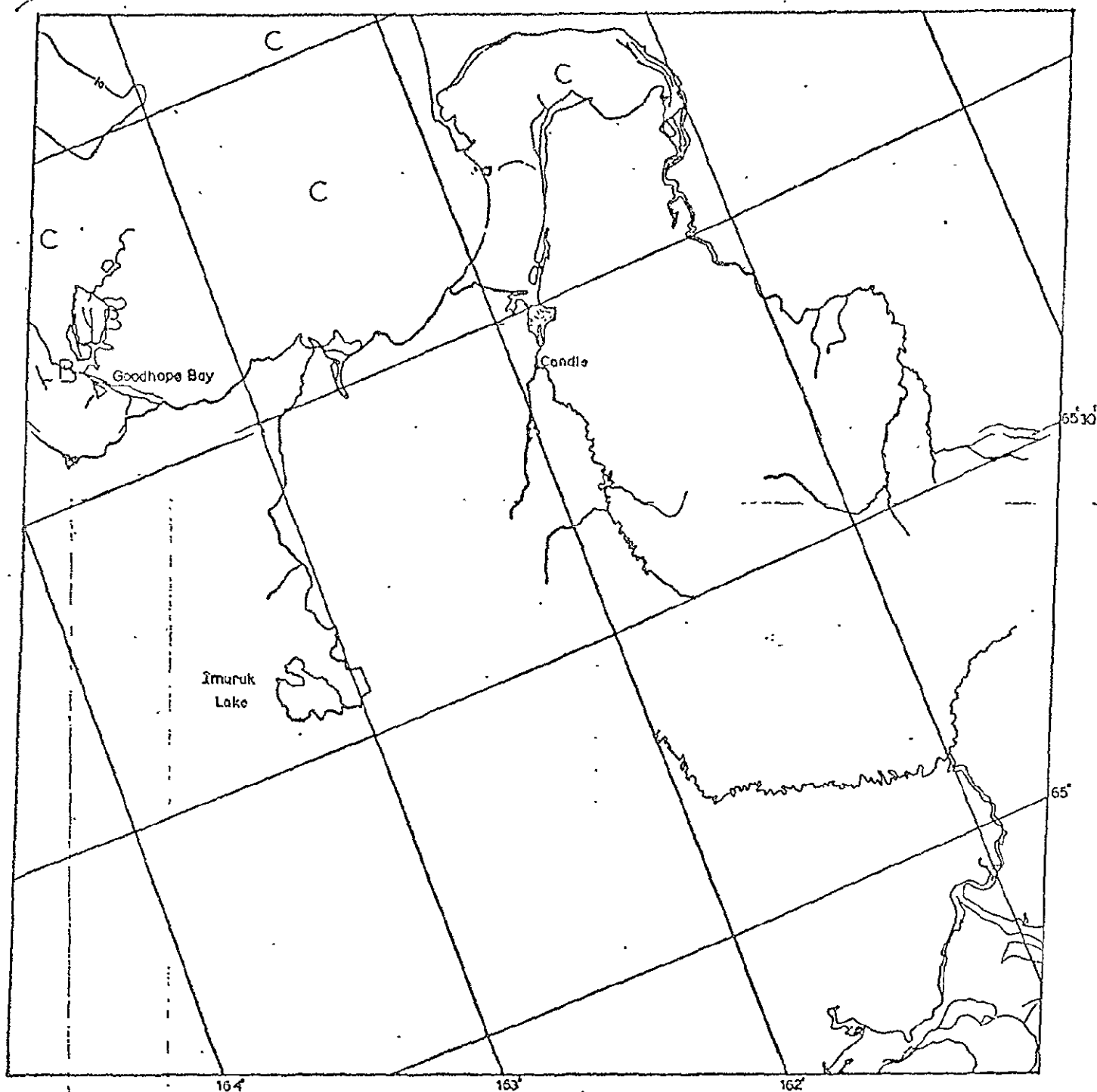




KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

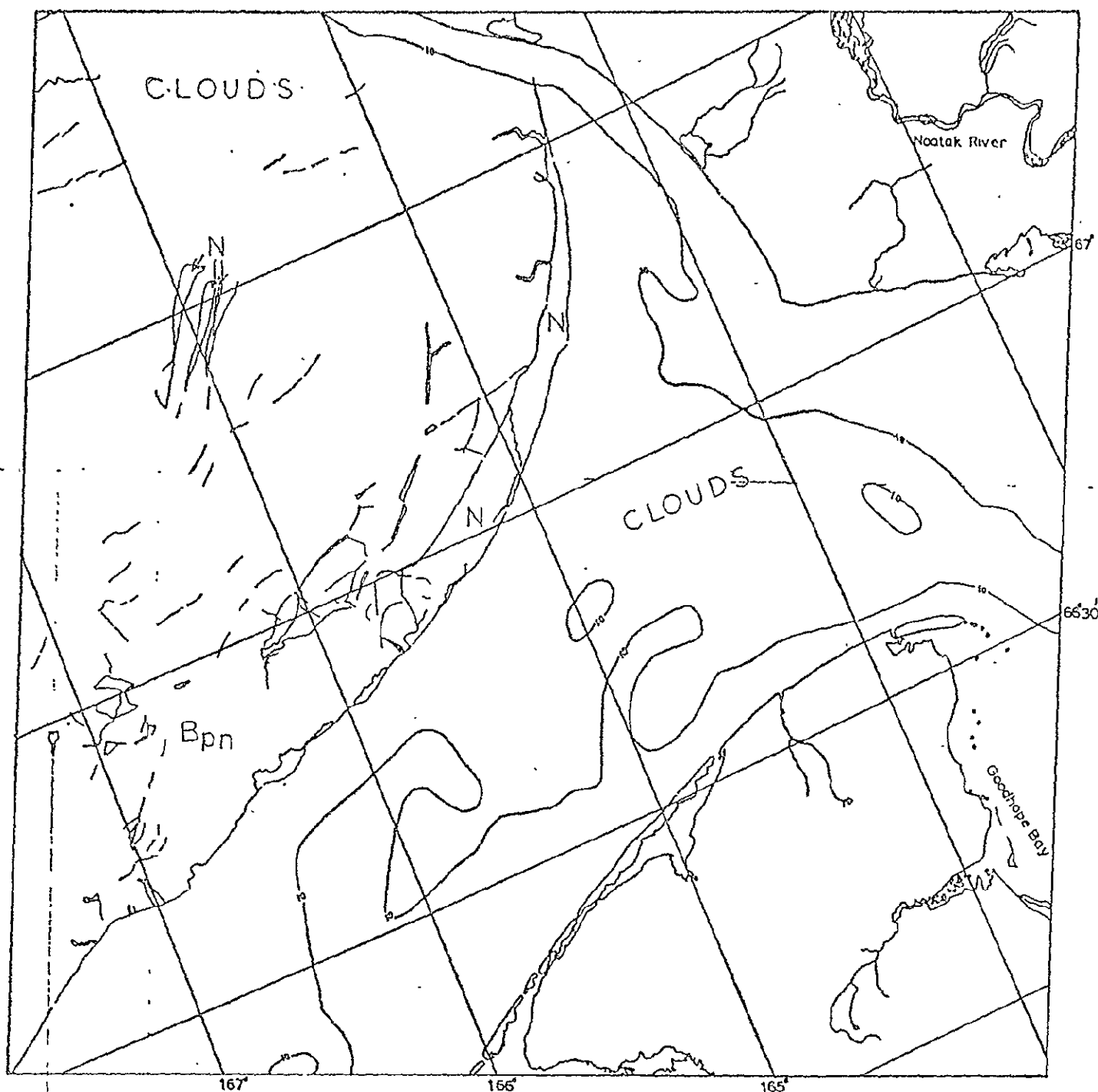
E-1582-21481-7  
25 FEB. 1974



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

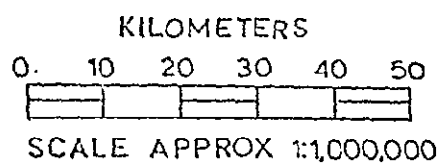
CHUKCHI SEA

E-1582-21483-7  
25 FEB. 1974



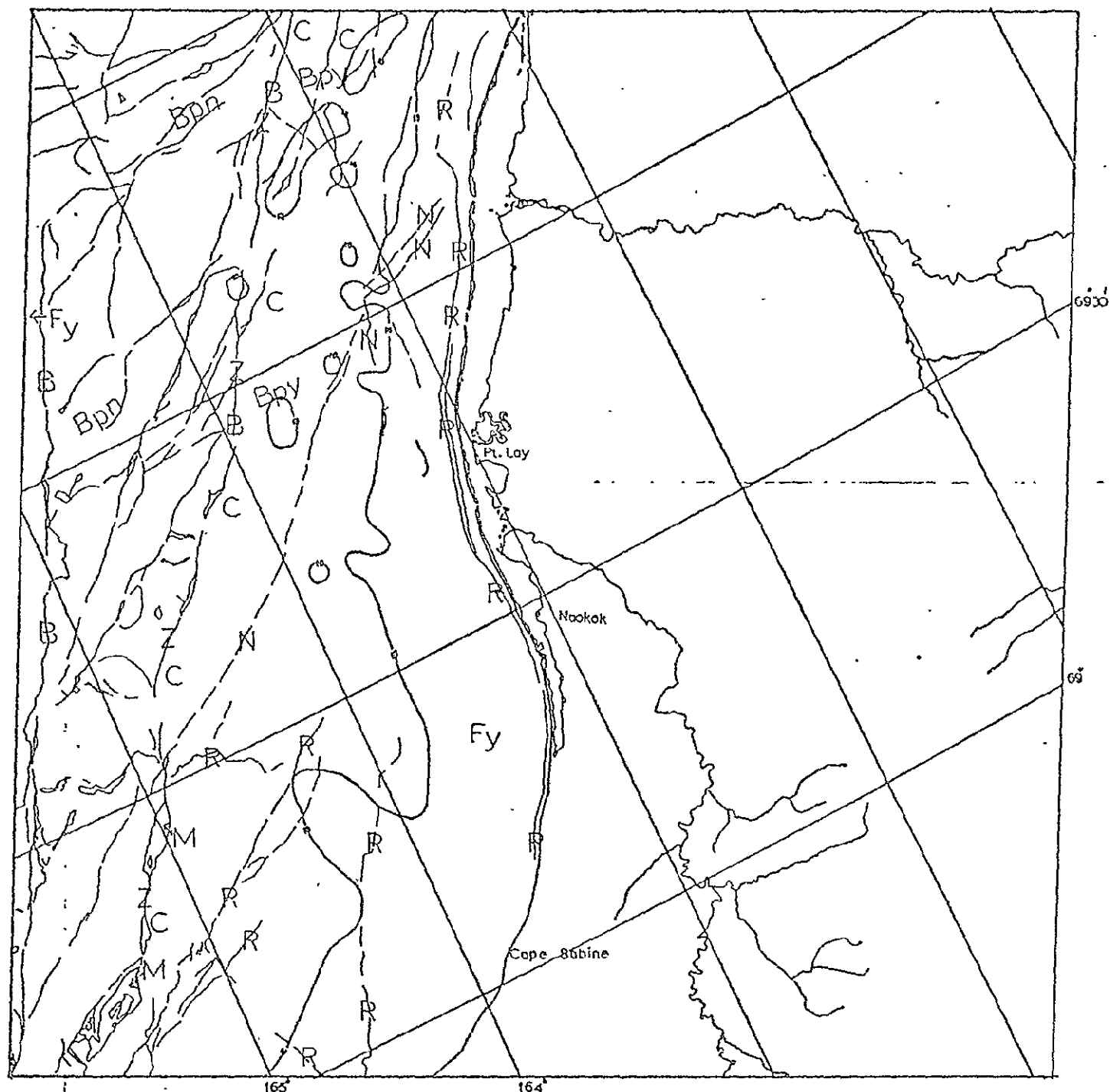
Entire scene covered with thin clouds.

E-1585-22052-7  
28 FEB. 1974



CHUKCHI SEA.

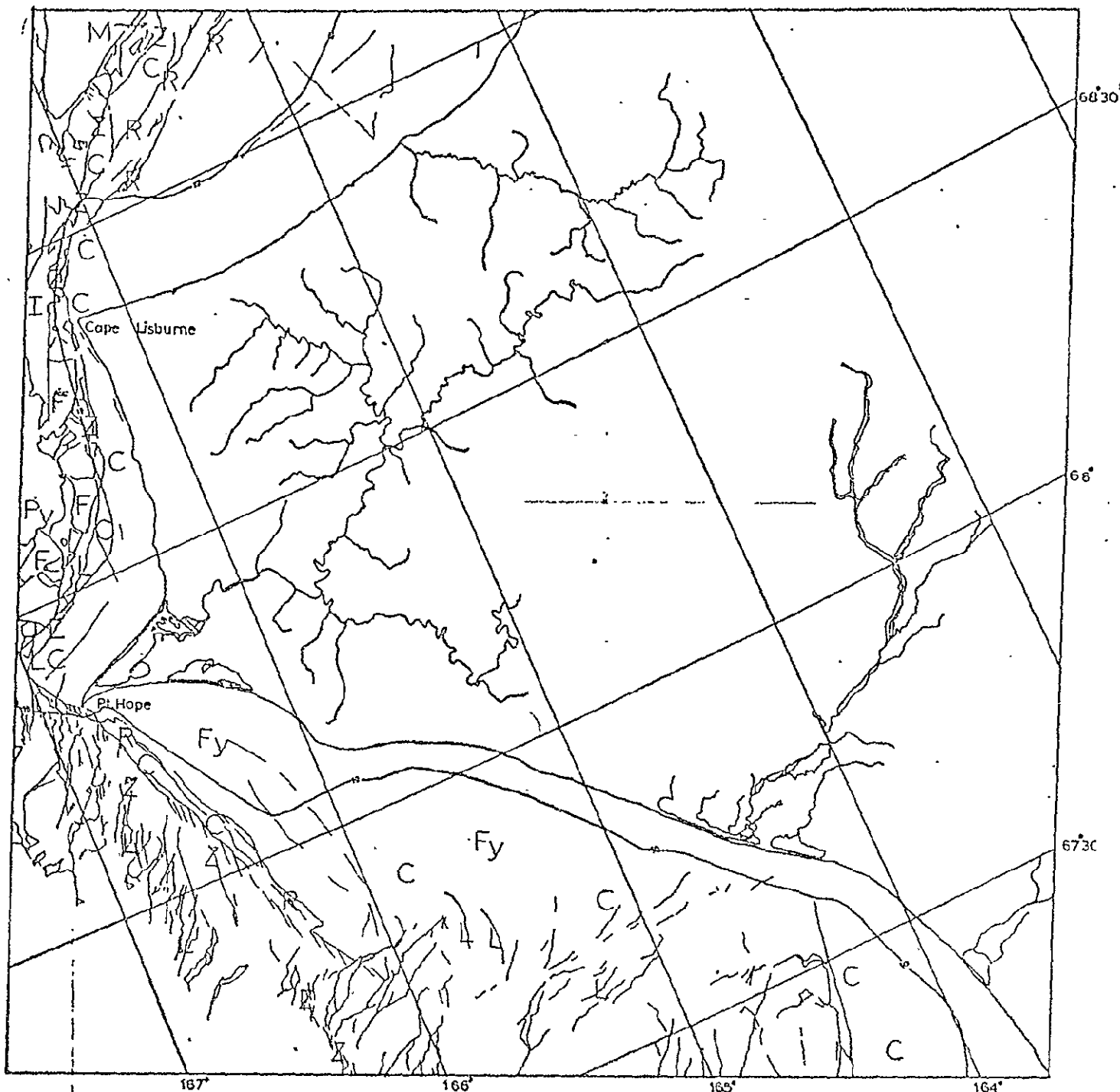




KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

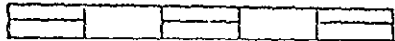
CHUKCHI SEA

E-1586-22101-7  
 1 MARCH 1974



KILOMETERS

0 10 20 30 40 50

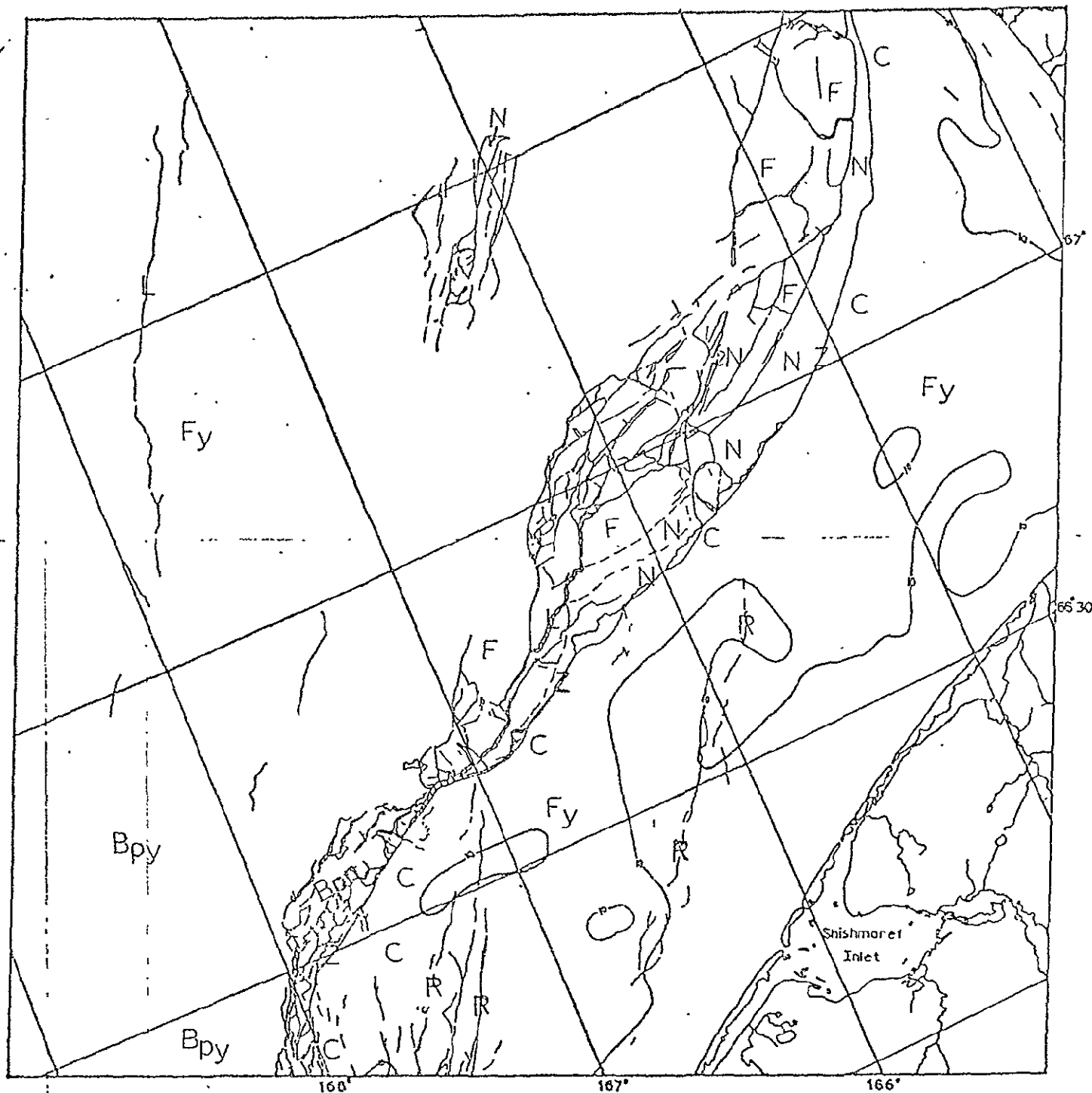


SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1586-22104-7

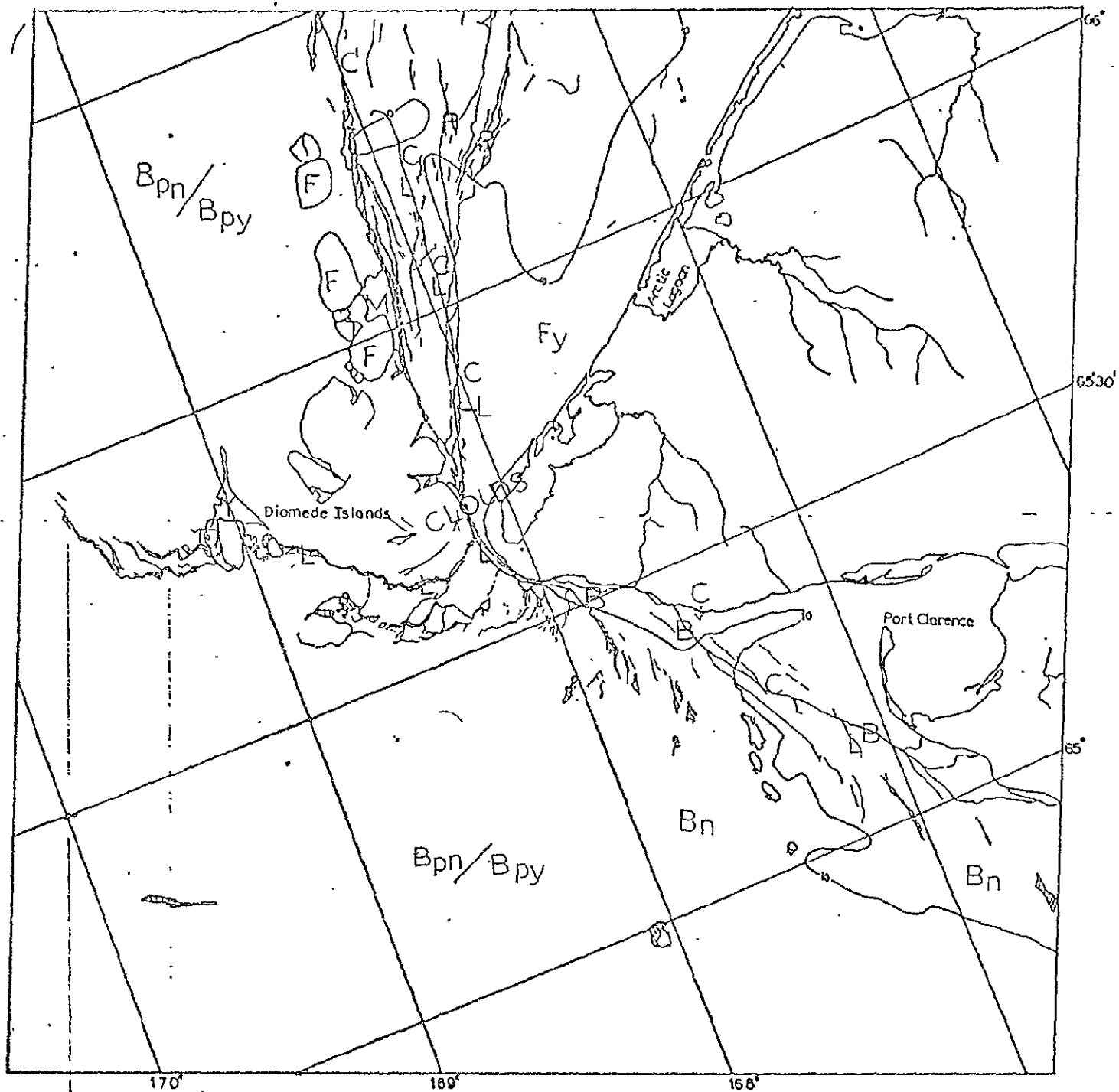
1 MARCH 1974



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1586-22110-7  
1 MARCH 1974

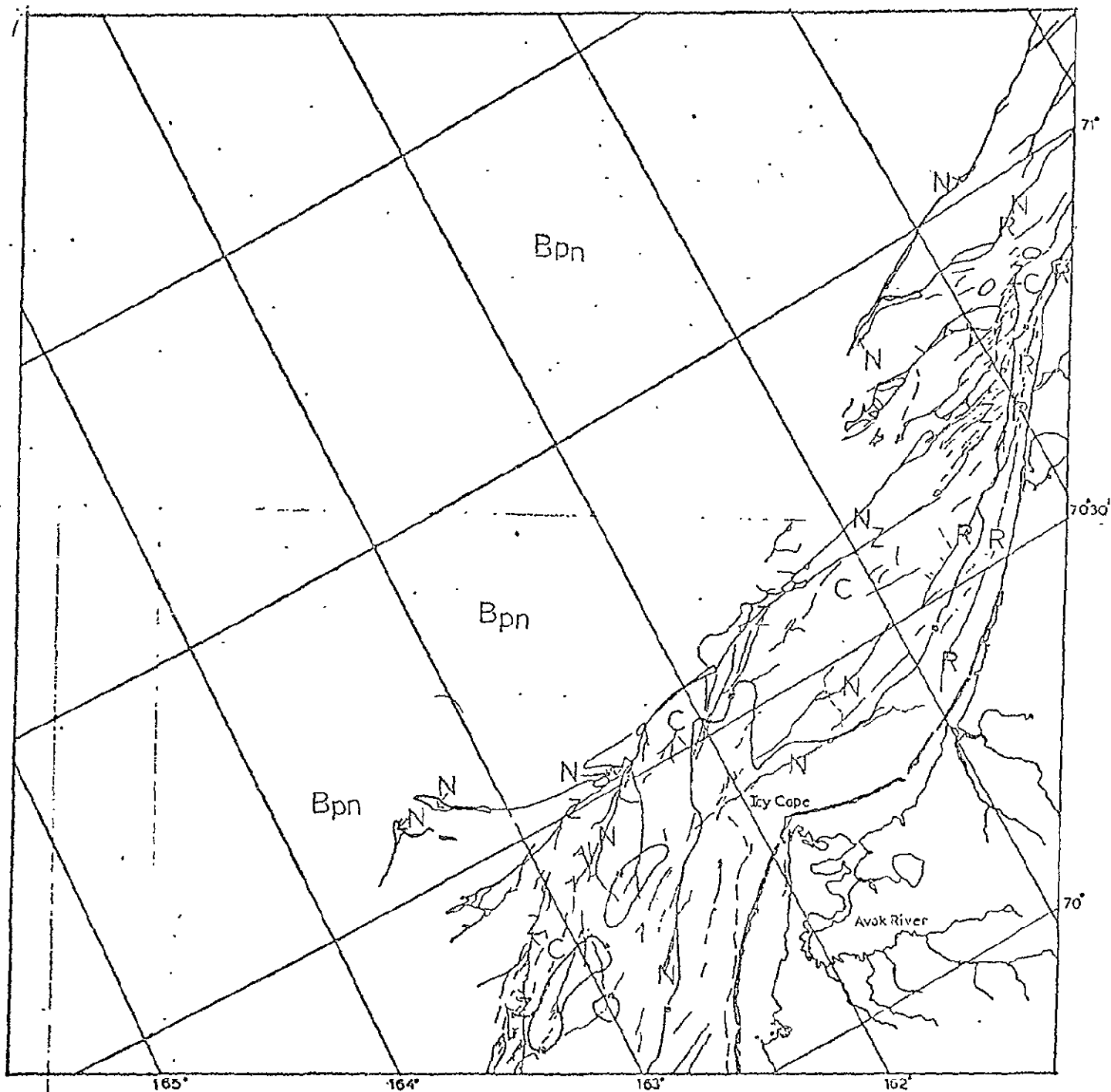


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1586-22113-7  
 1 MARCH 1974

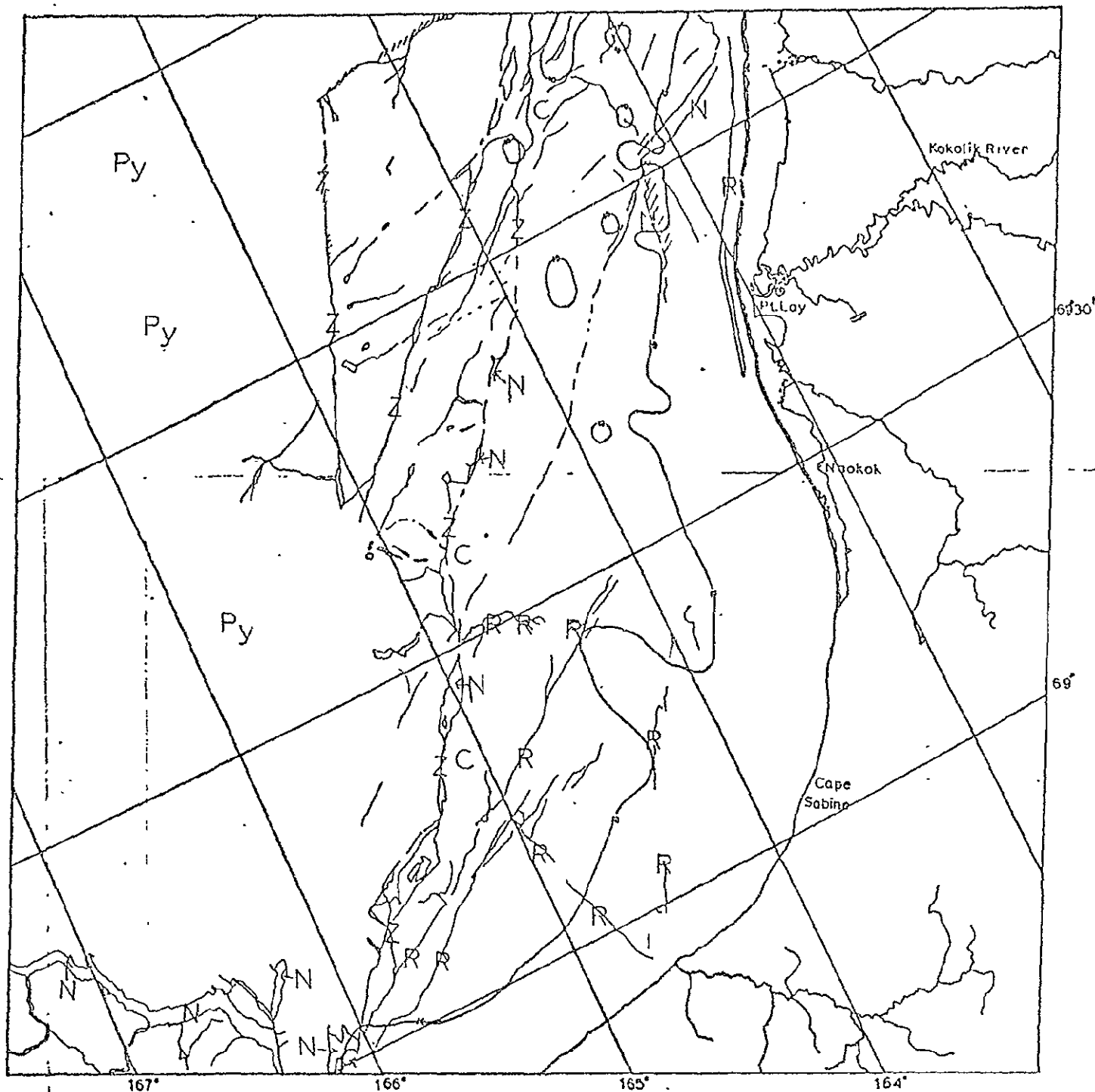




KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

E-1587-22153-7  
 2 MARCH 1974

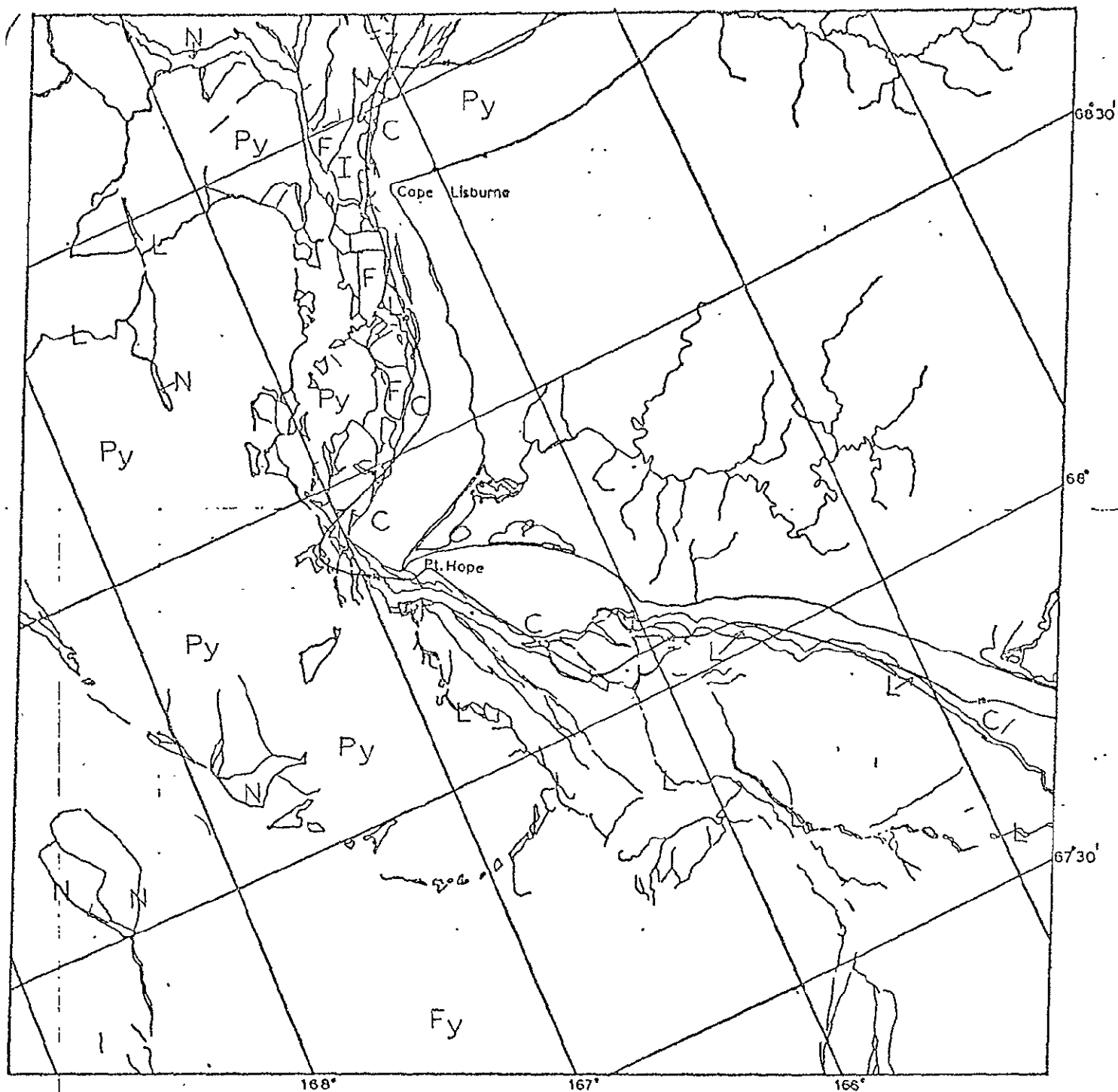
CHUKCHI SEA



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

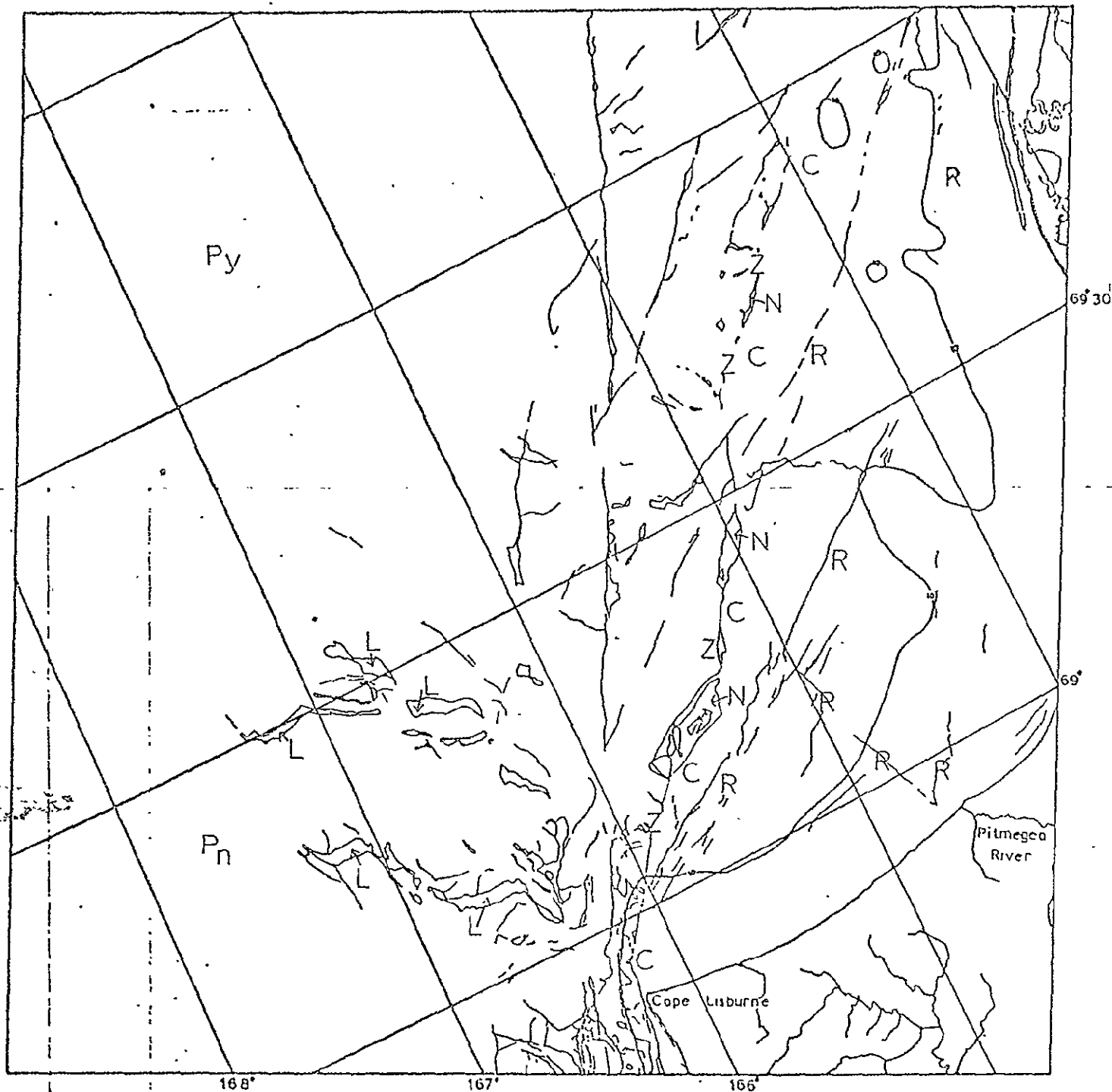
E-1587-22160-7  
 2 MARCH 1974



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

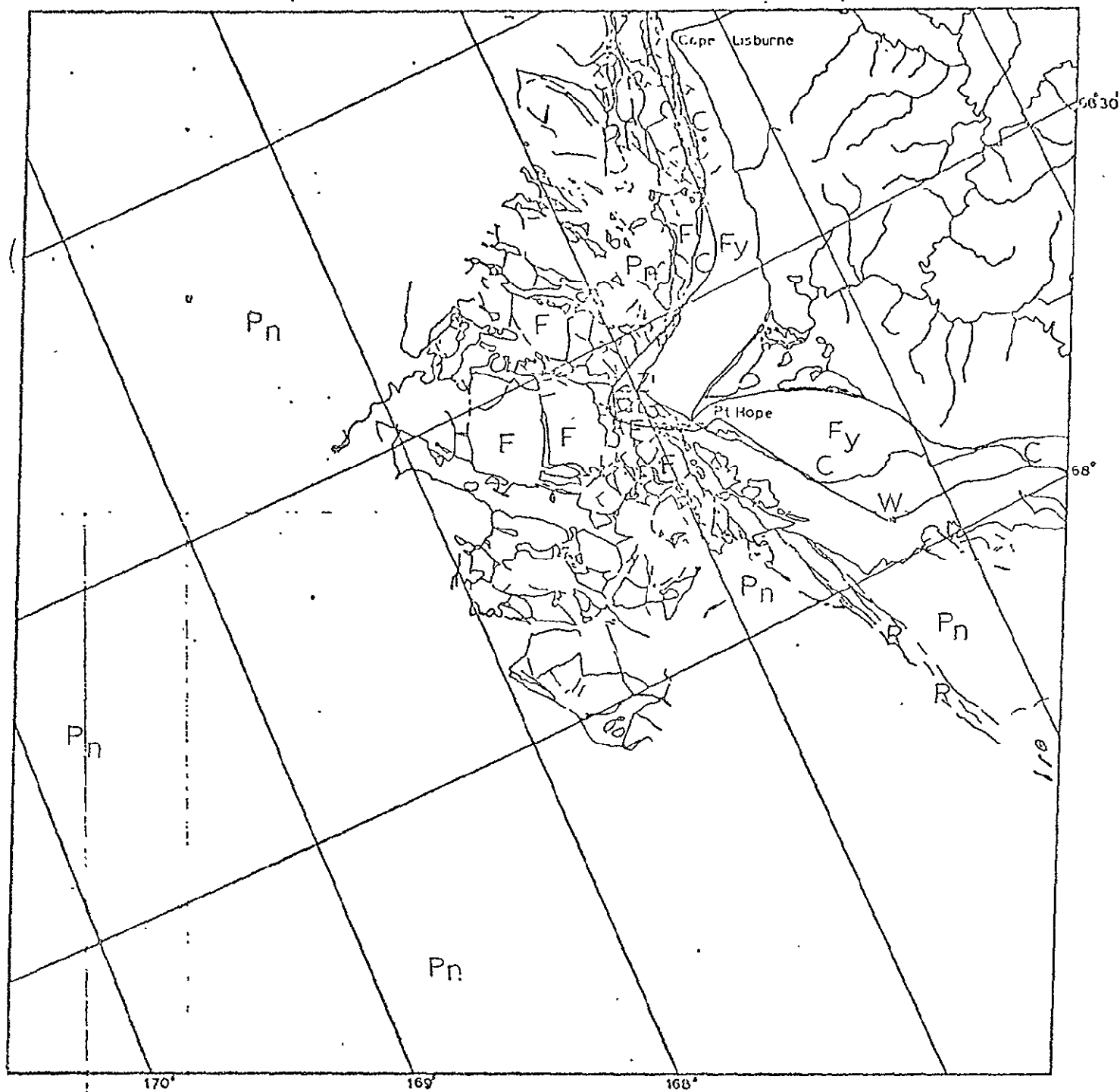
E-1587-22162-7  
2 MARCH 1974



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1588-22214-7  
 3 MARCH 1974



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

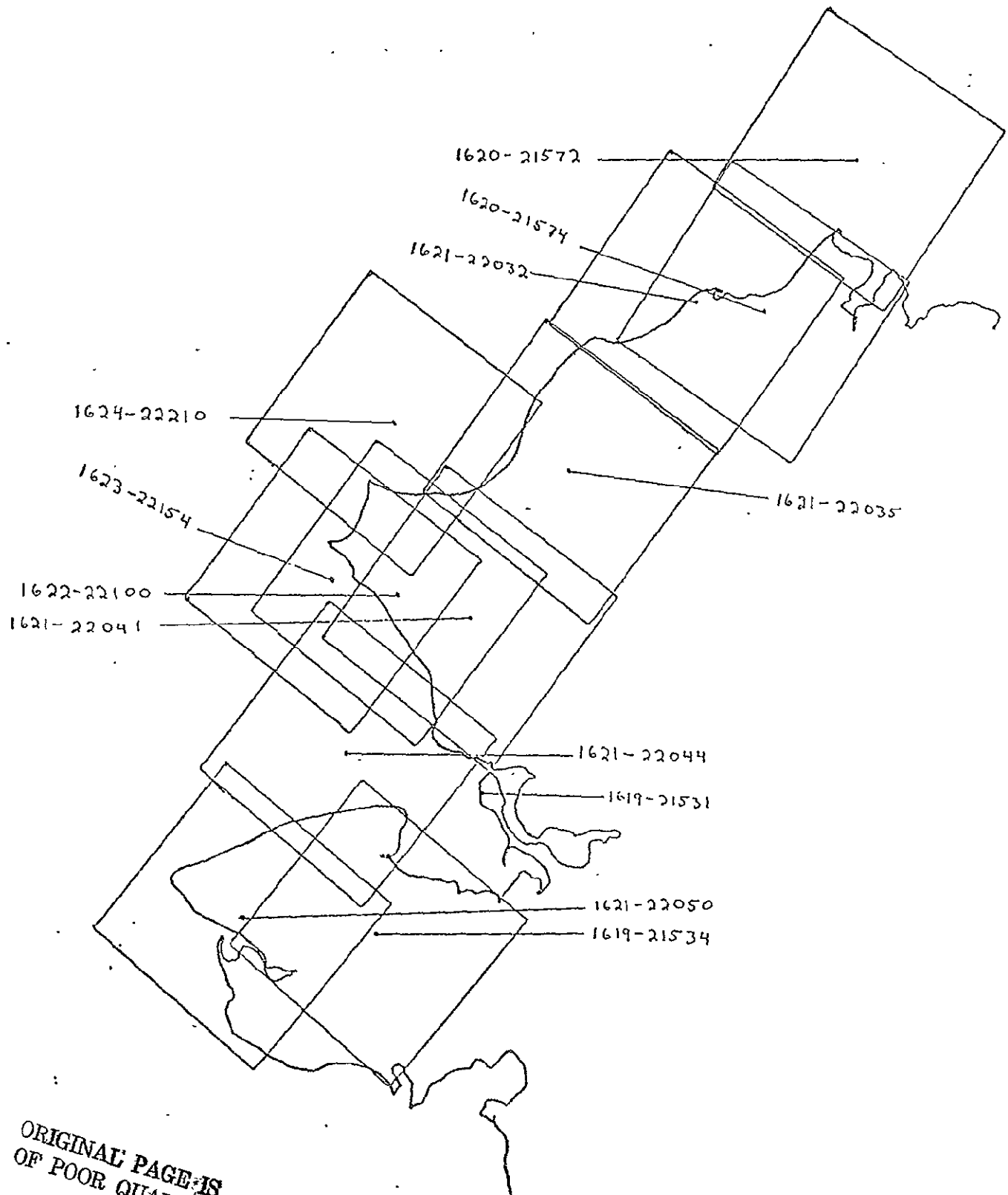
CHUKCHI SEA

E-1508-22220-7  
 3 MARCH 1974

# CHUKCHI SEA

2-19 APRIL 1974

Cycle 1618-1635



ORIGINAL PAGE IS  
OF POOR QUALITY

Scenes    1619-21531  
          1619-21534  
          1620-21572  
          1620-21574  
          1621-22032  
          1621-22035  
          1621-22041  
          1621-22044  
          1621-22050  
          1622-22100  
          1623-22154  
          1624-22210

These scenes show the Chukchi coast between Barrow and Cape Rodney for April 3-8, 1974. It is apparent that considerable ice motion had been taking place recently but has ceased long enough for the formation of new ice. Very recently a new lead has opened up running down the coast at places somewhat off shore from the contiguous ice from Barrow to Cape Lisburne ending there in a system of polynyas. Starting from a polynya south of Point Hope a recently formed lead forms the edge of contiguous ice across the outer portion of Kotzebue Sound, and then after approaching the coast south of Cape Espenberg, strikes seaward meeting fractured ice and open water approximately 50 km north of Bering Strait.

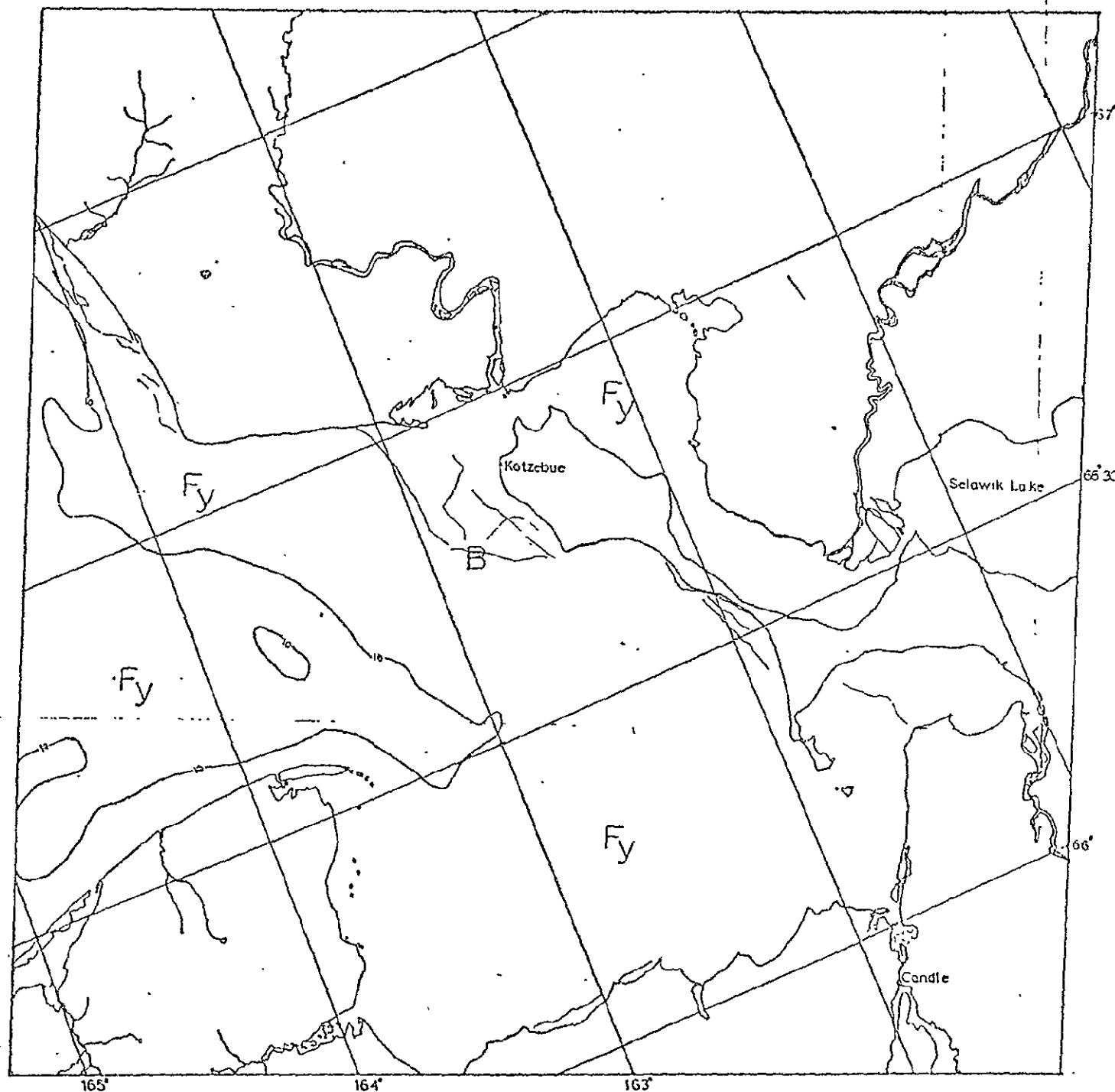
At Bering Strait the edge of contiguous ice strikes west of north from Cape Prince of Wales while the coast runs east of north. Hence a large triangularly shaped area of contiguous ice is formed with the closed lead striking seaward from the Espenberg Peninsula as the northern boundary. This piece of contiguous ice is situated over shoals and may be grounded. The entire Kotzebue Sound is contiguous ice at this time. Southeast of Point Hope a large polynya forms the seaward boundary of contiguous ice.

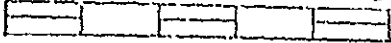
Northwest of Point Hope a large apron of contiguous ice can be found situated above shoals in the same location. This apron ends midway between Point Hope and Cape Lisburne where the edge of contiguous ice abruptly moves almost to the shore line---well inshore of the 10-fathom contour.

North of Cape Lisburne is another large apron of contiguous ice with many indications of current and past stress relief. Just as with the apron of contiguous ice north of Point Hope, the edge of contiguous ice then runs shoreward coming quite close to shore well within the 10-fathom contour.

The edge of contiguous ice then moves seaward passing Blossom Shoals well seaward of the 10-fathom contour (but perhaps controlled by shoals more seaward than the Blossom group) and then coastward to pass Point Franklin in close coincidence with the 10-fathom contour, and again passing Barrow close to the 10-fathom contour.

Evidence of ridging can be found in the contiguous ice off Barrow, parallel to the coast past Point Franklin, on Blossom Shoals and north of Cape Prince of Wales.

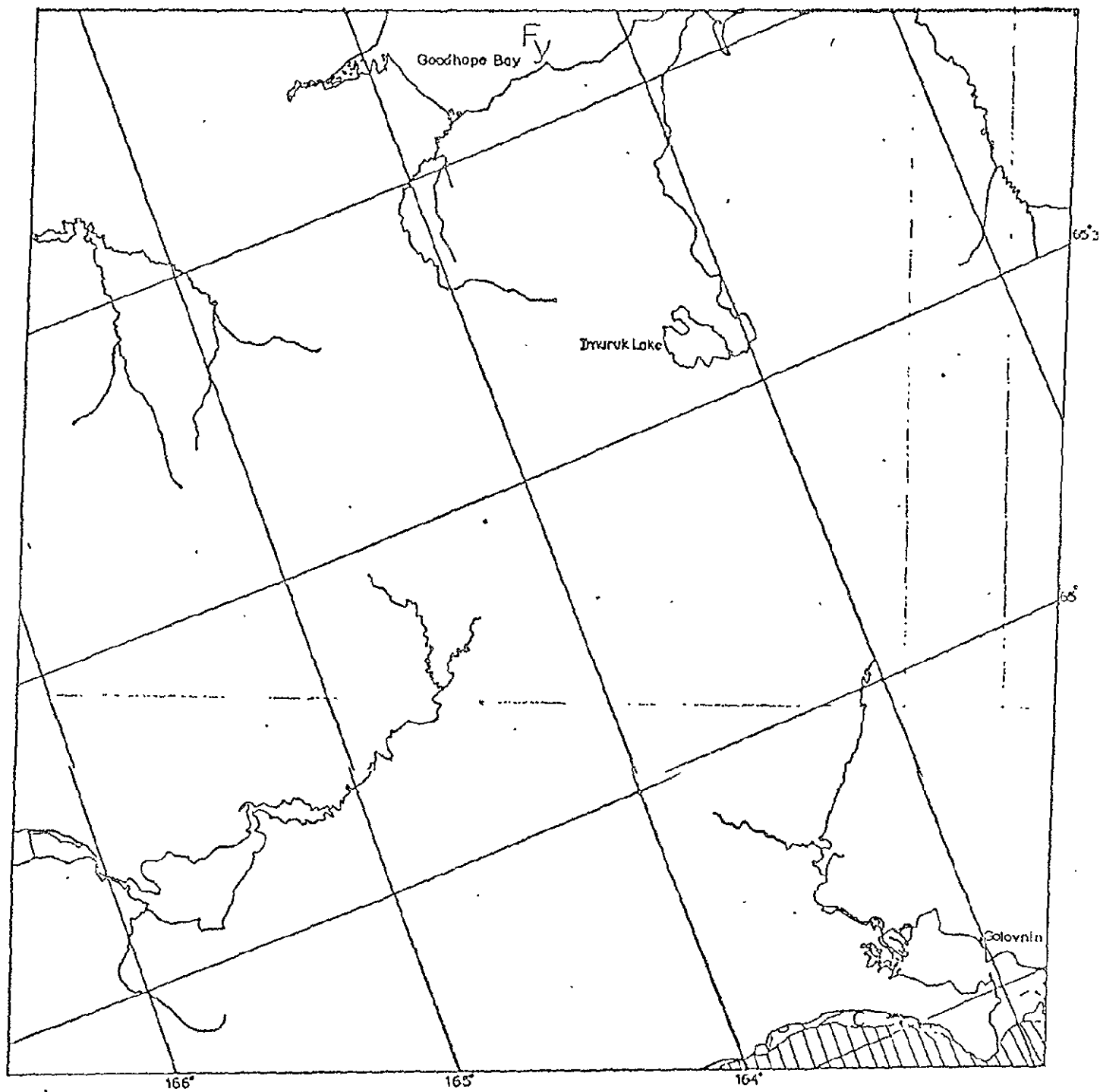


KILOMETERS  
 0 10 20 30 40 50  
  
 SCALE APPROX 1:1,000,000

E-1619-21531-7  
 3 APRIL 1974

CHUKCHII SEA

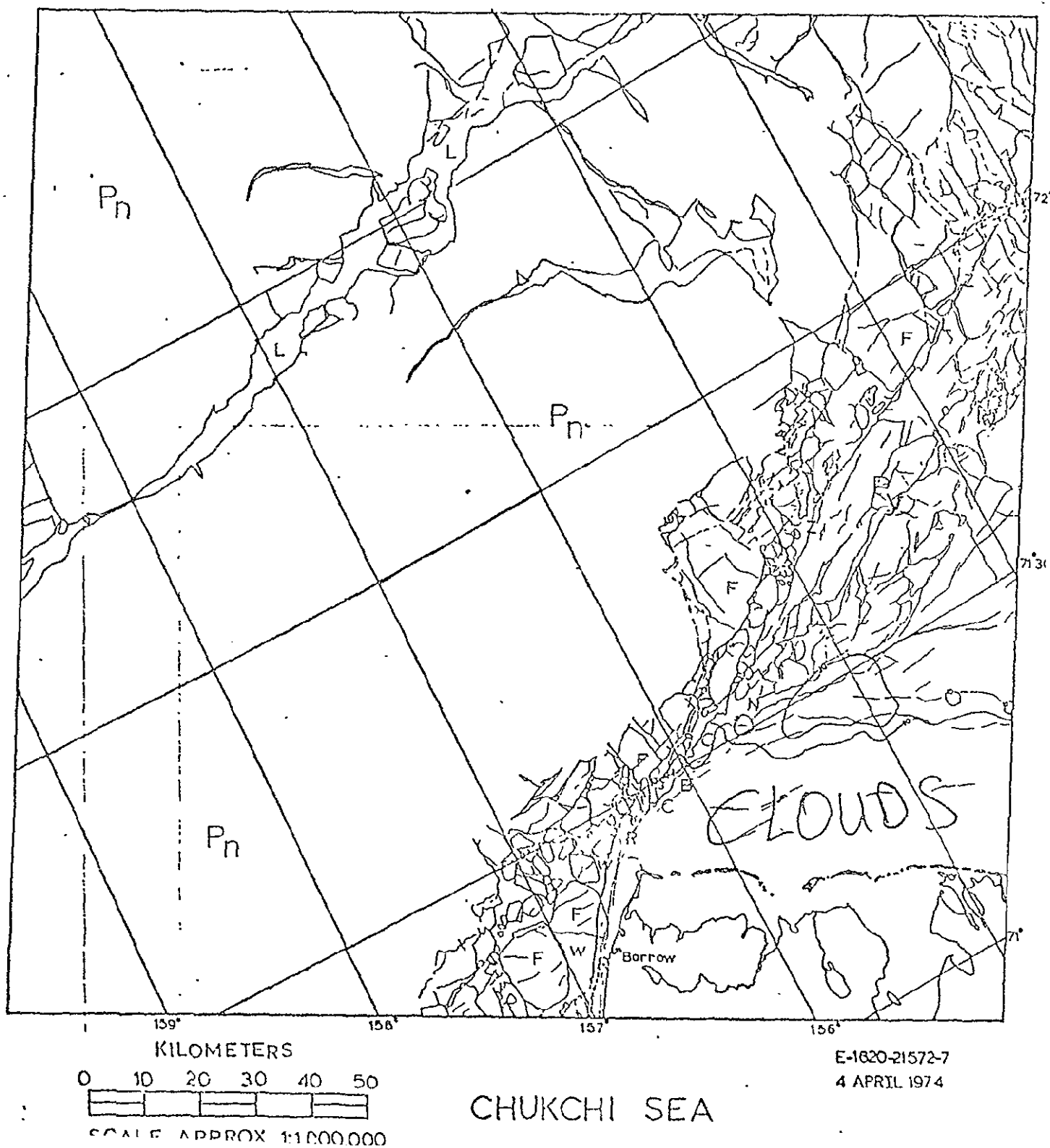


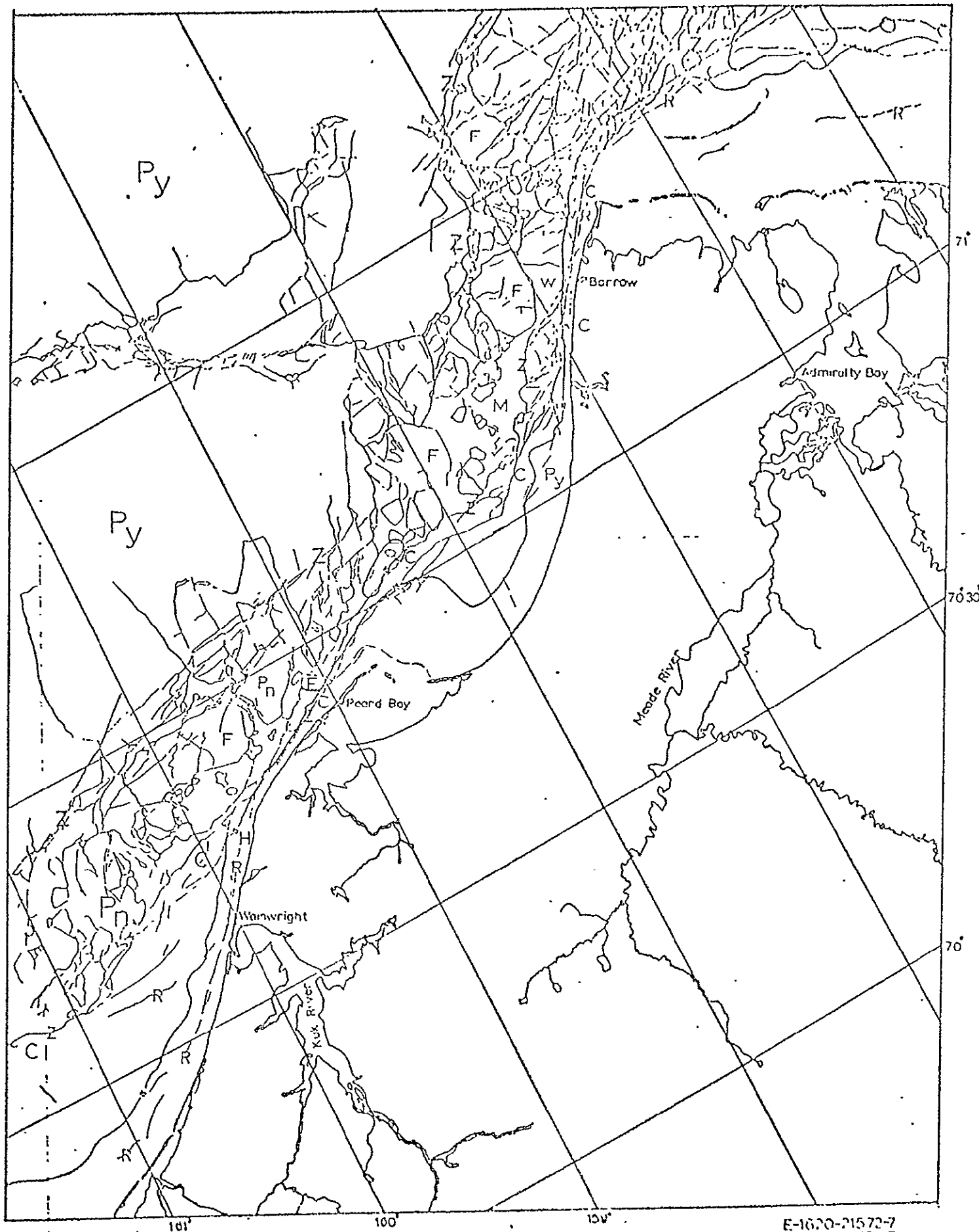


0 10 20 30 40 50  
KILOMETERS  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1619-21534-7  
3 APRIL 1974



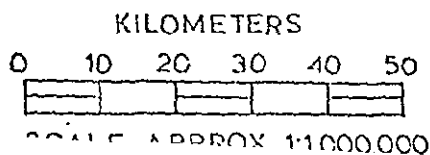
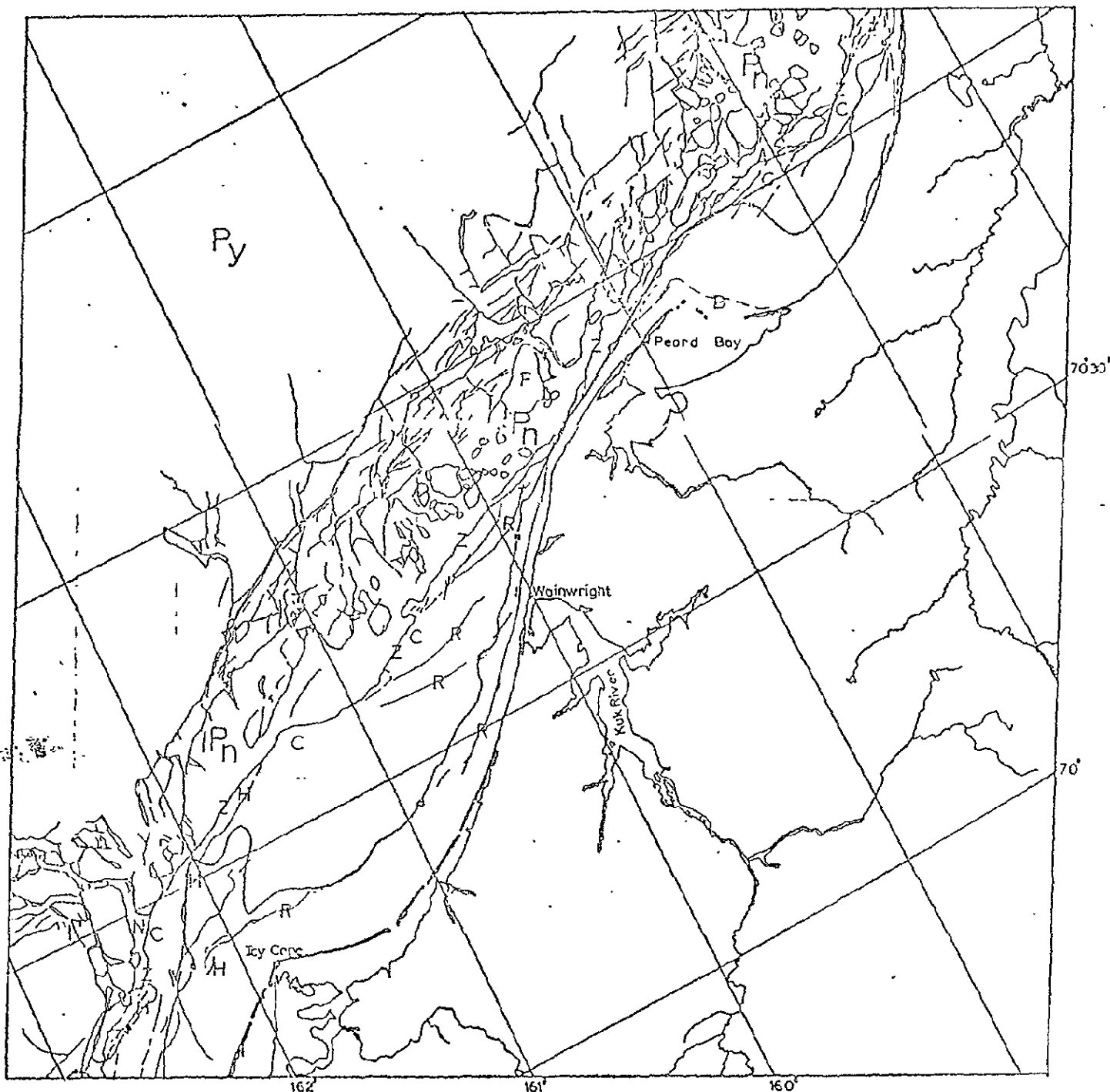


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

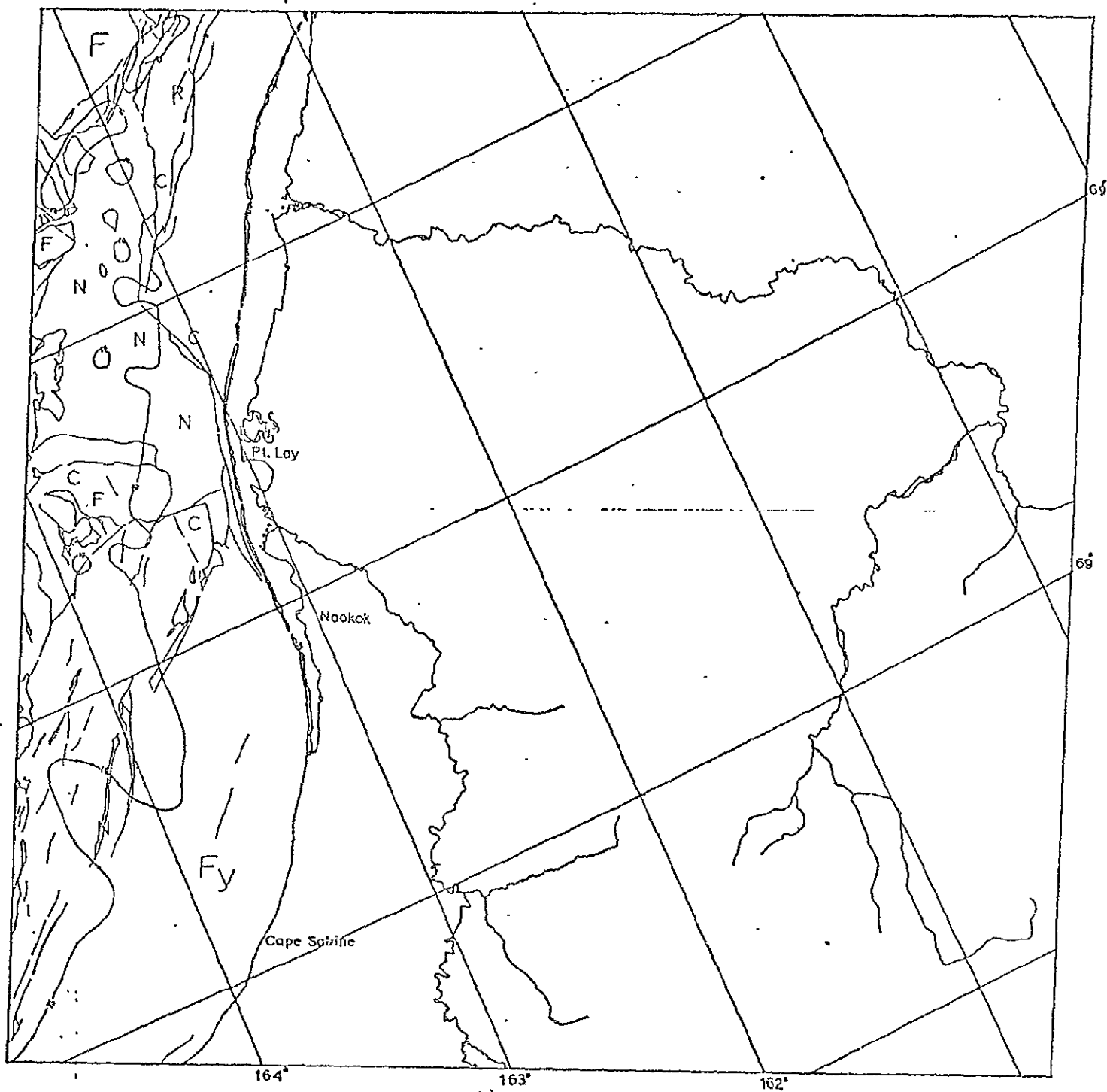
CHUKCHI SEA  
 147

E-1620-21572-7  
 E-1620-21574-7

4 APRIL 1974



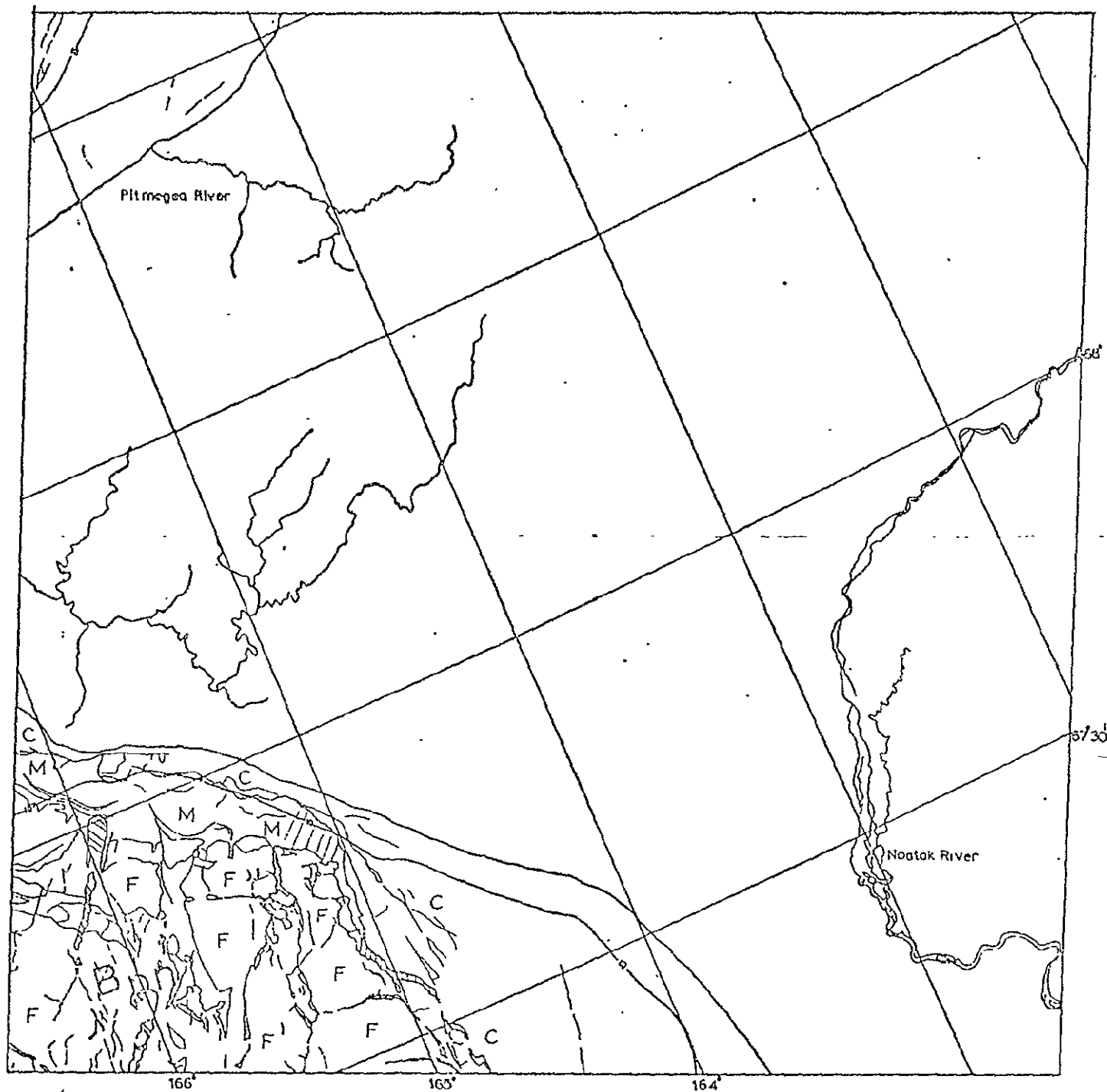
E-1621-22032-7  
5 APRIL 1974



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1621-22035-7  
 5 APRIL 1974

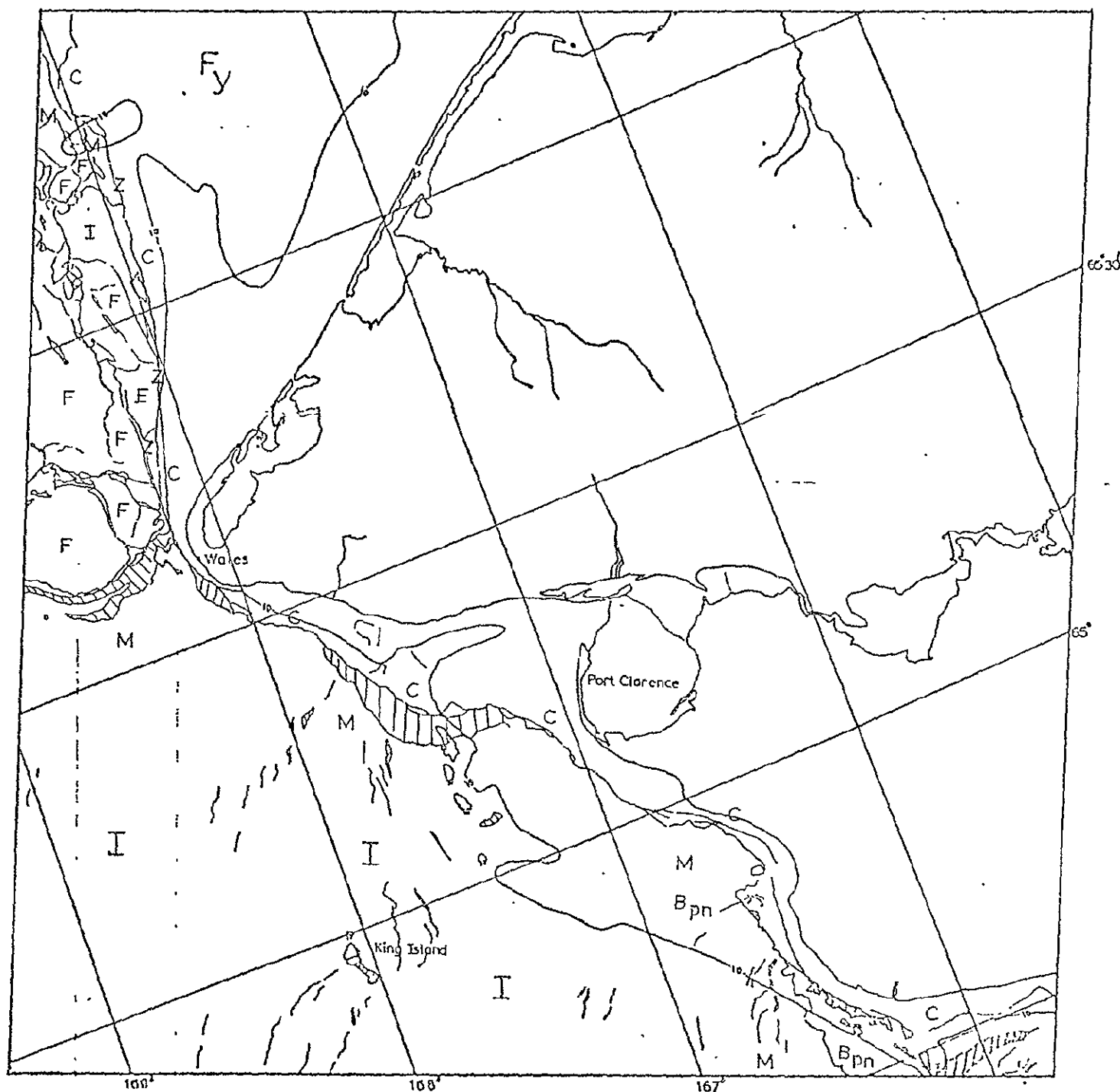


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

E-1621-22041-7  
5 APRIL 1974

CHUKCHI SEA



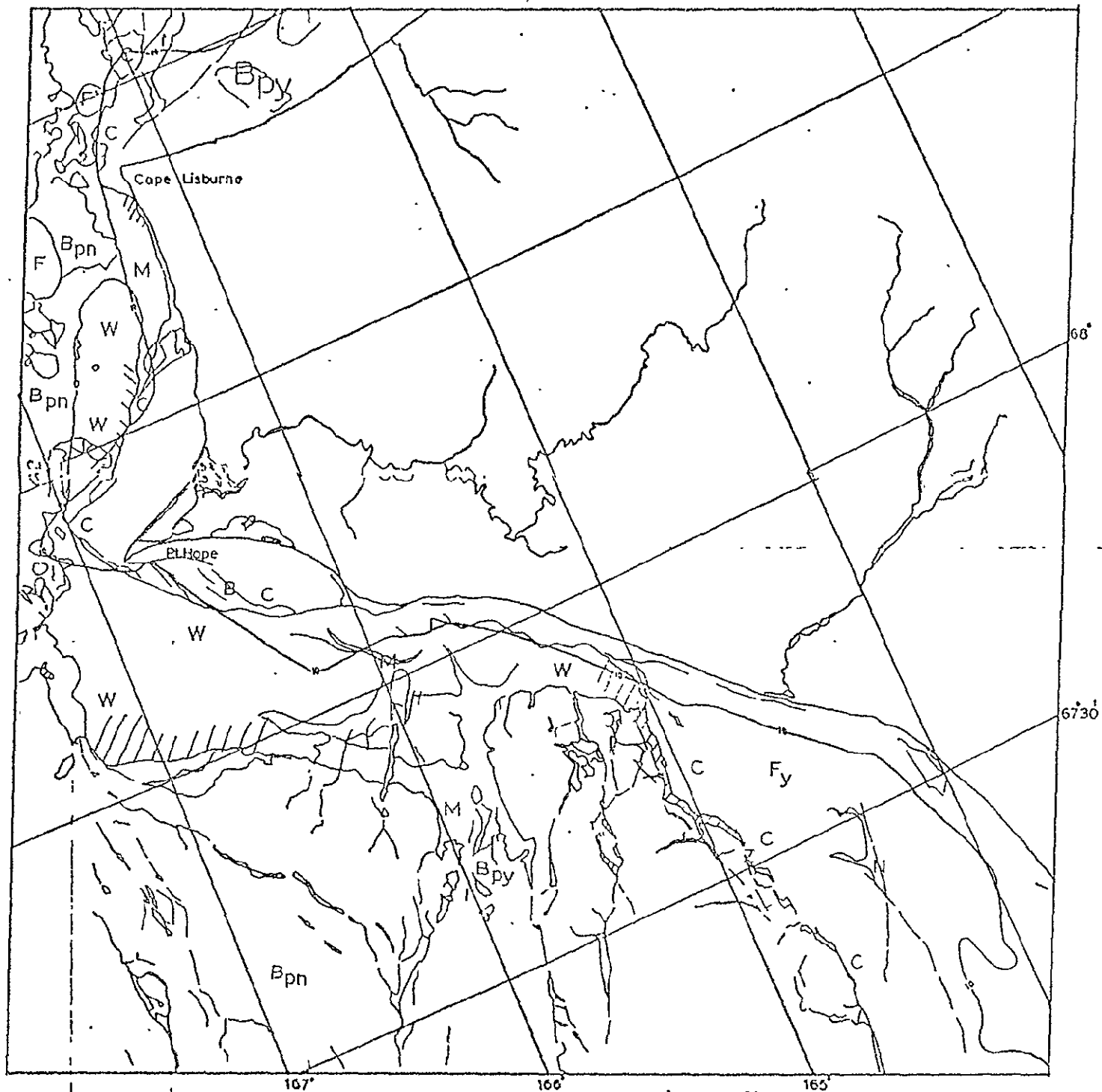


KILOMETERS  
0 10 20 30 40 50

CHUKCHI SEA

E-1621-22050-7  
5 APRIL 1974

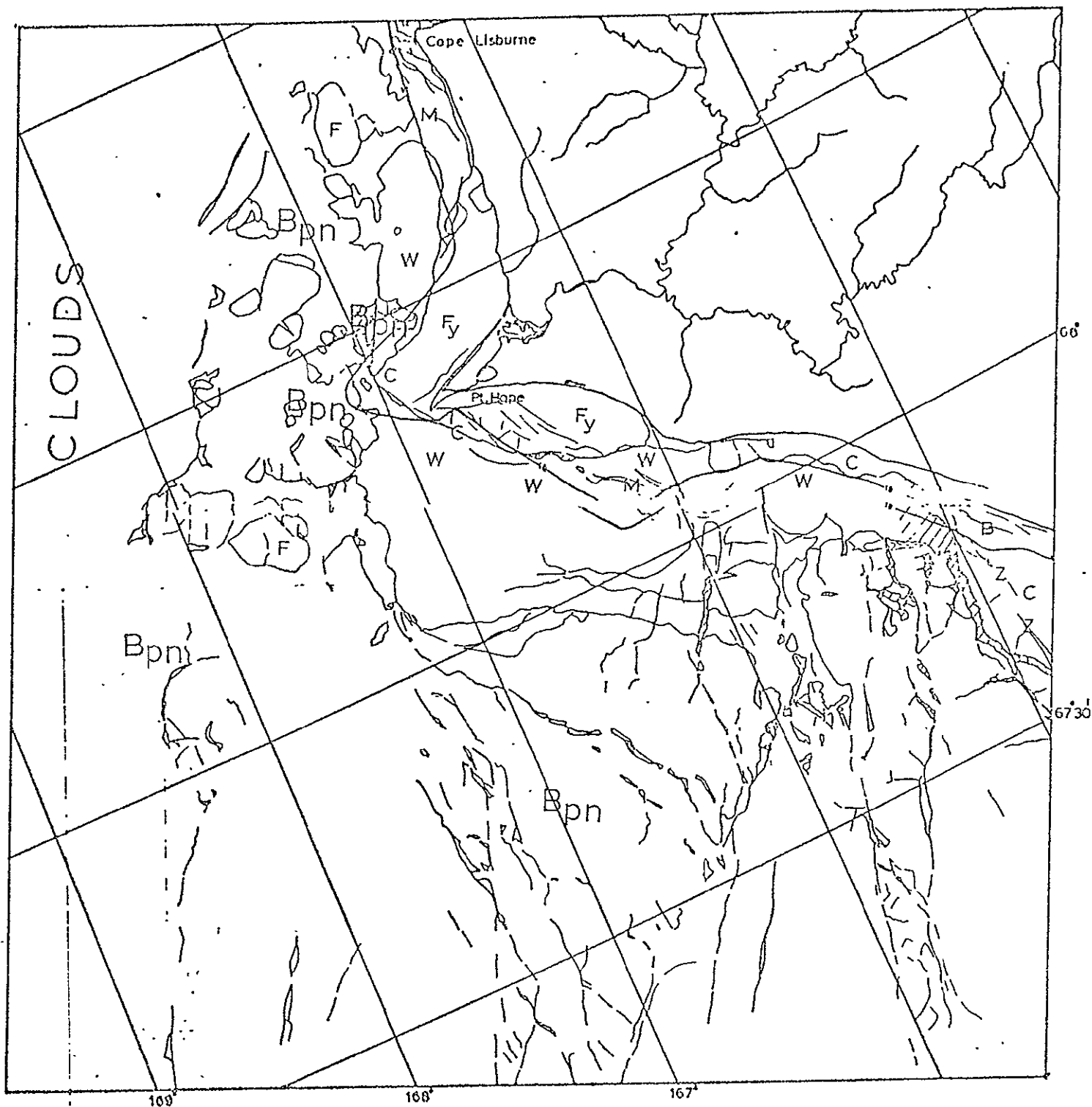




KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

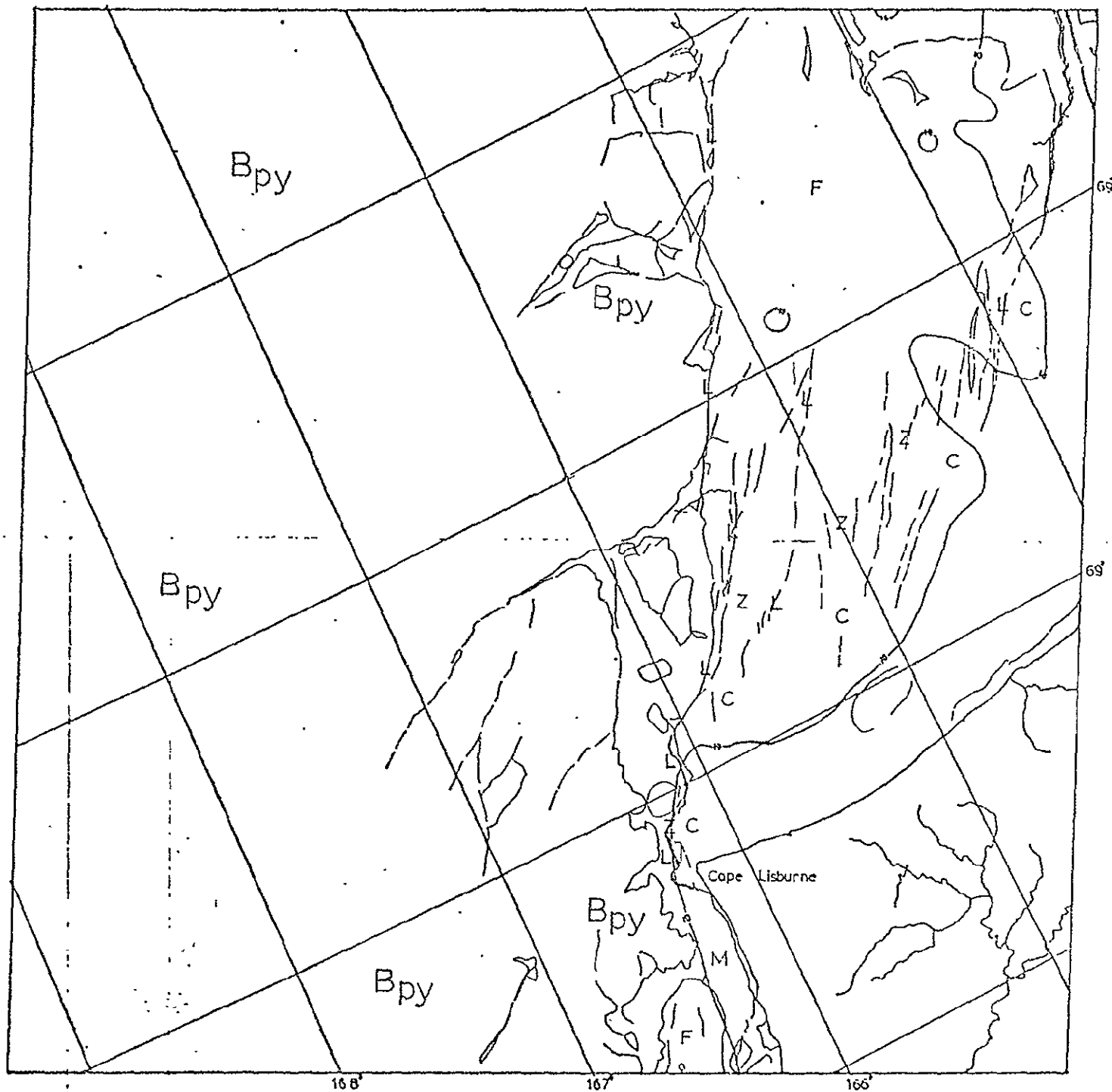
E-1622-22X00-7  
 6 APRIL 1974



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1623-22154-7  
7 APRIL 1974



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

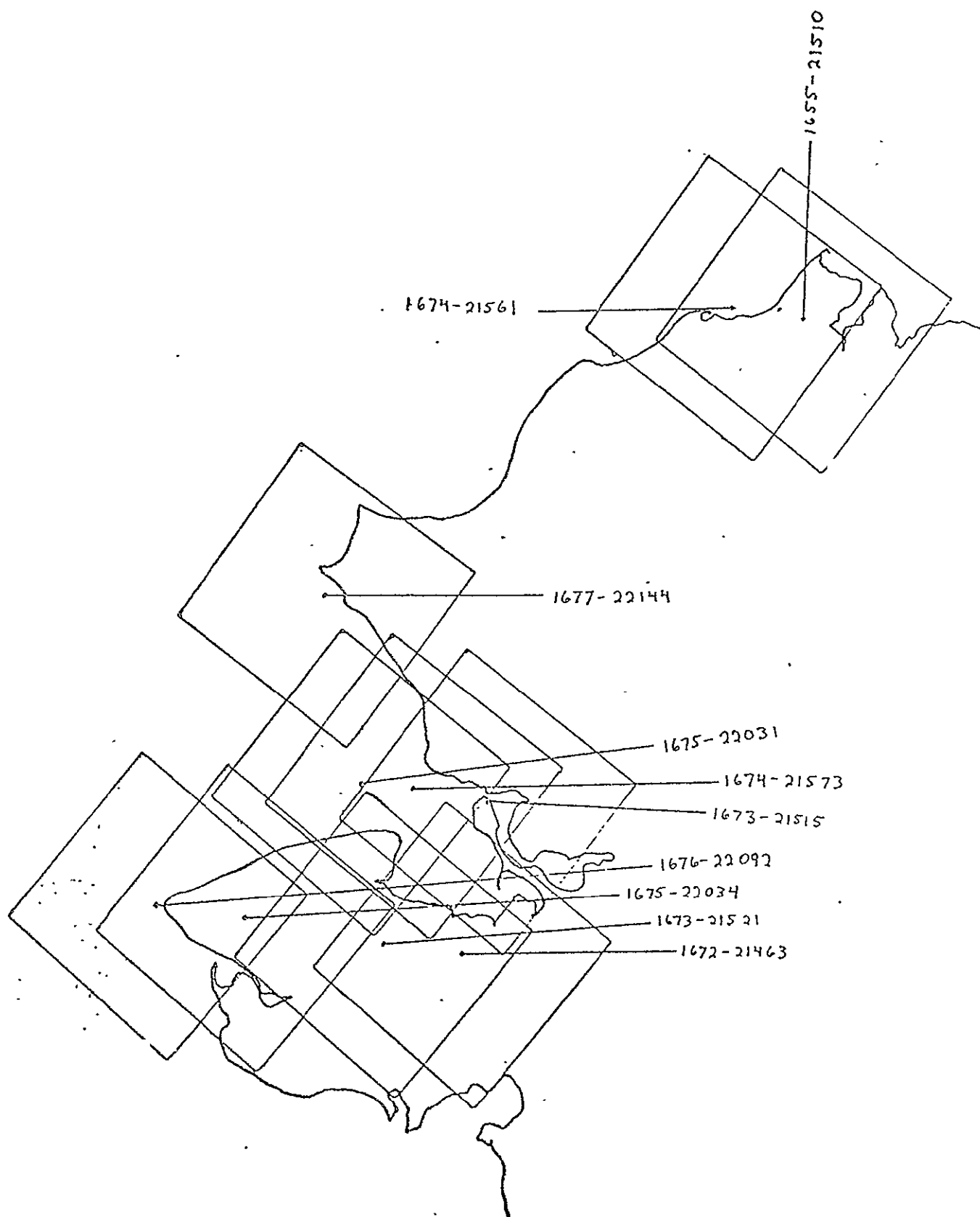
CHUKCHI SEA

E-1624-22210-7  
8 APRIL 1974

# CHUKCHI SEA

26 MAY - 12 JUNE 1974

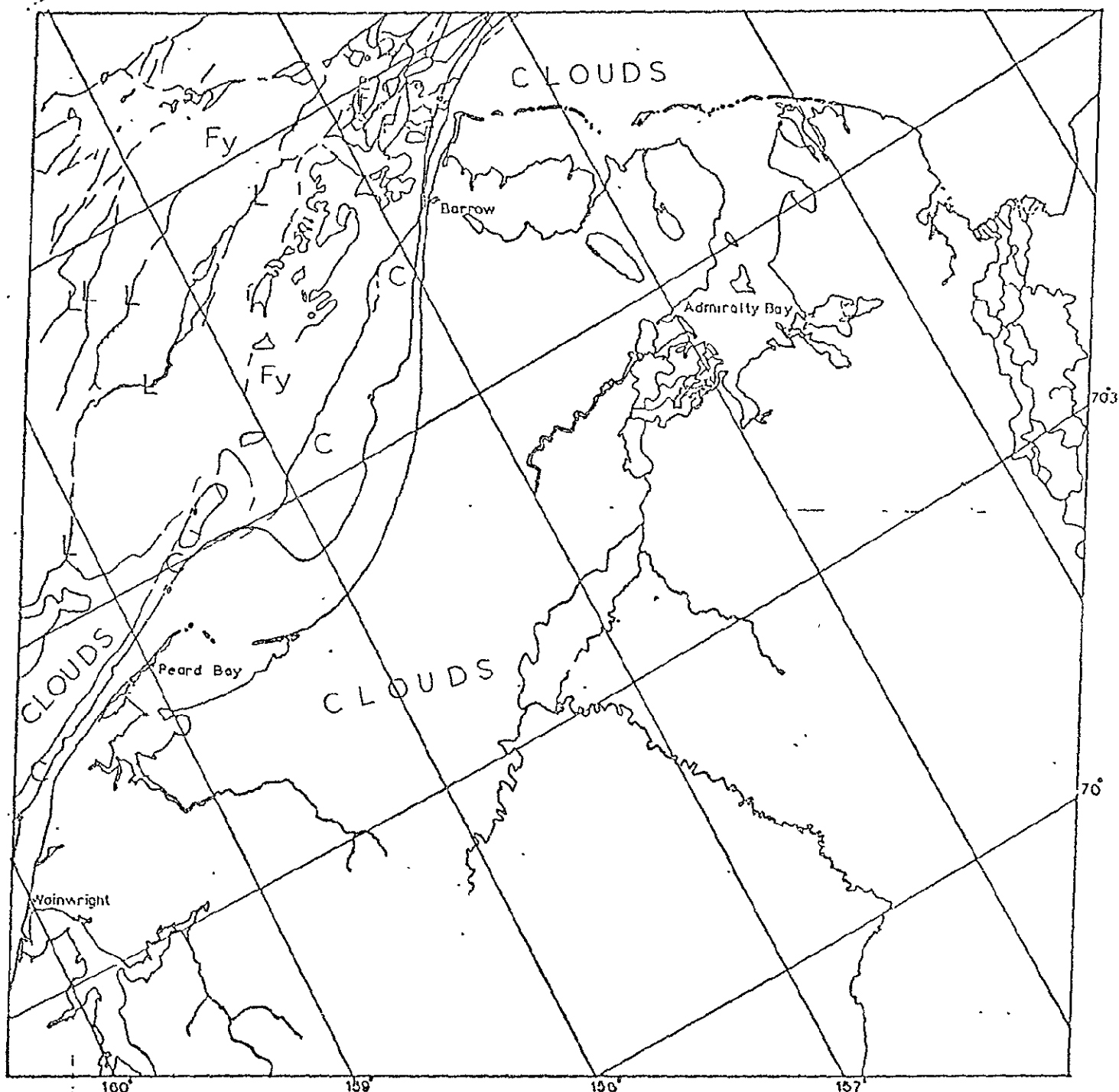
Cycle 1672 - 1689



Scenes    1672-21463  
          1673-21515  
          1673-21521  
          1674-21561  
          1674-21573  
          1675-22031  
          1675-22034  
          1676-22092  
          1676-22141

These scenes show the Chukchi coast for the period May 26-31, 1975 between Bering Strait and Barrow with the exception of a few areas in between. At this time the oceanic ice has been broken into pans and no freezing is taking place. The chief value of this imagery is the identification of ice remaining contiguous with shore and hence the ice which has been protected by grounded ice features.

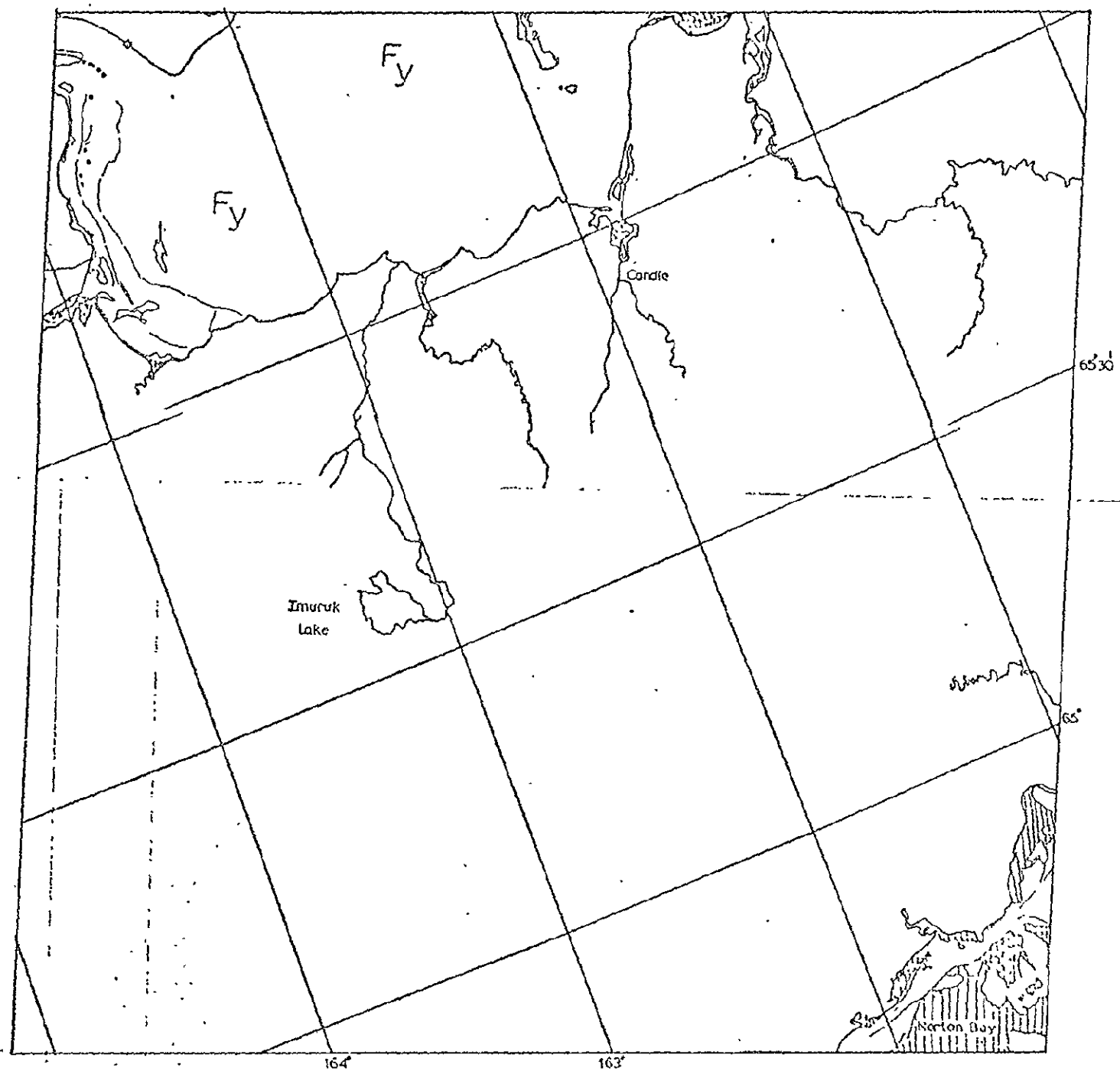
Starting northward from Cape Prince of Wales we note a large expanse of ice remaining over the shoals just to the north. There is evidence of ridges on the seaward boundary of this ice. The ice within Kotzebue sound remains in place and unbroken. It does not appear to be bounded by grounded ice. To the north, a small apron of ice remains next to the shore to Point Hope where again a large area of ice remains coinciding with shoals. This situation repeats at Cape Lisburne. Far to the north, an apron of ice remains off Wainwright and Point Franklin apparently held in place by grounded ridges.



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

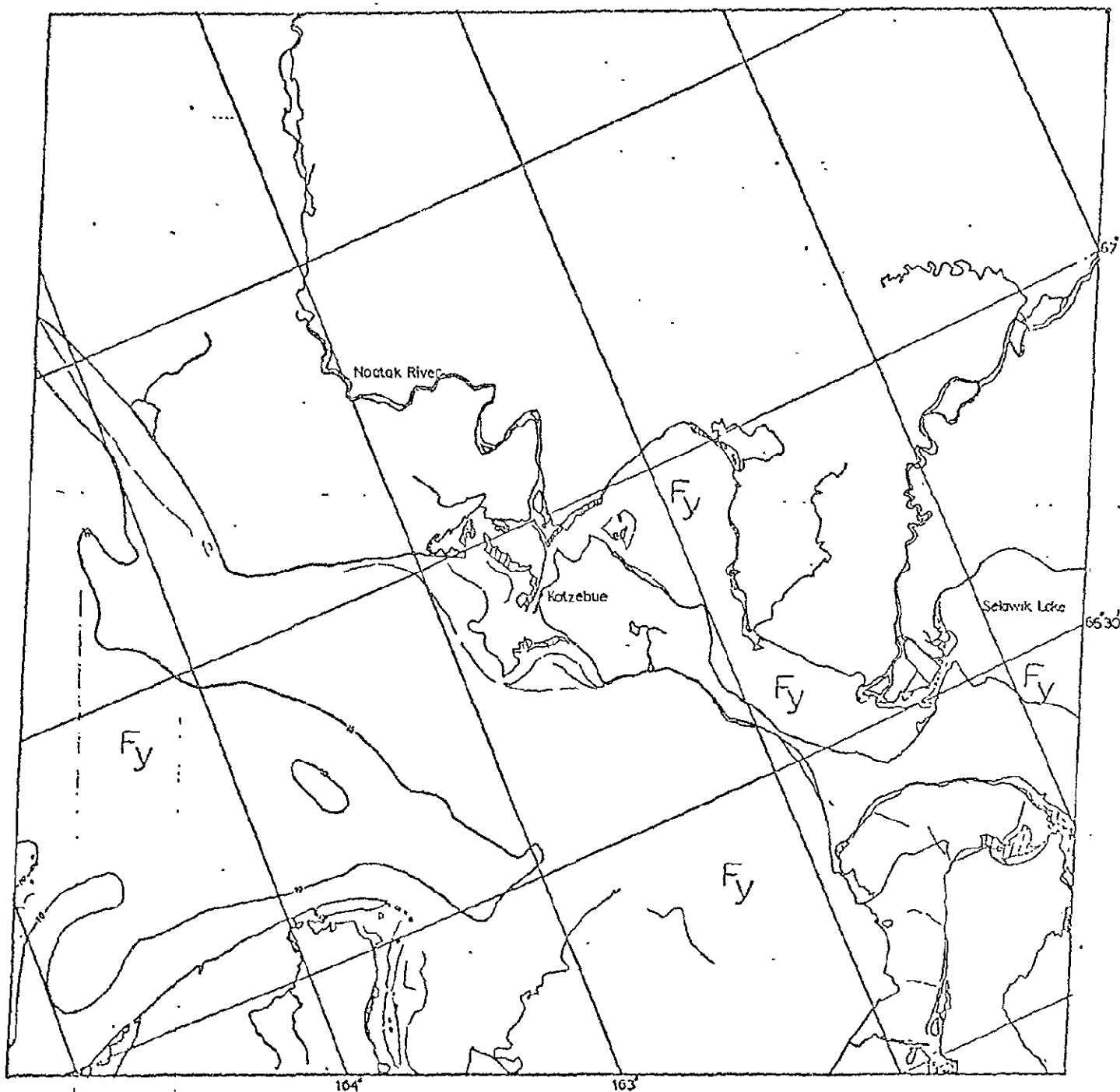
E-1655-21510-7  
 9 MAY 1974



KILOMETERS  
0 10 20 30 40 50  
APPROX 1:1,000,000

E-1672 21463-7  
26 MAY 1974

CHUKCHI SEA

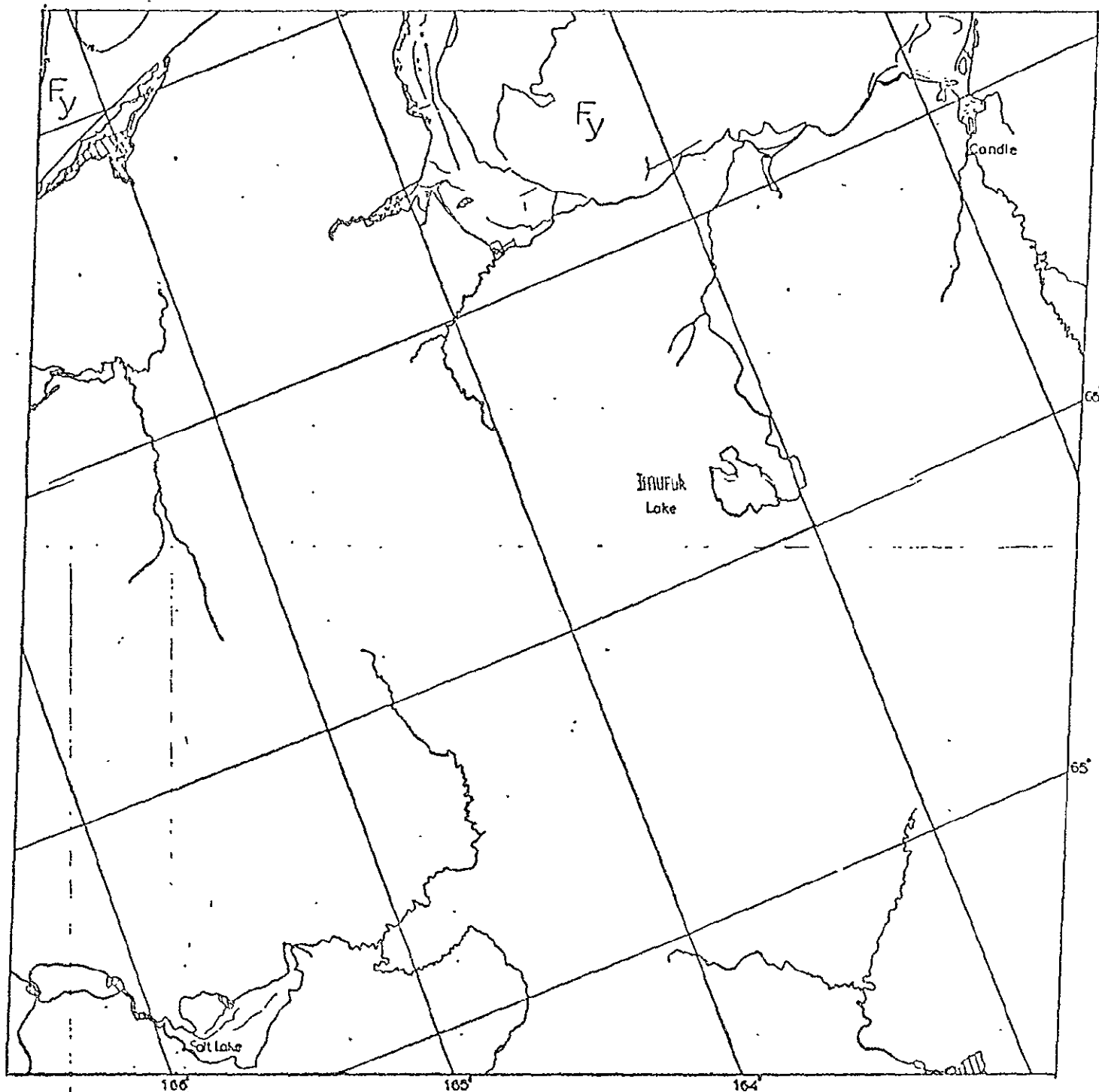


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1673-21515-7  
 27 MAY 1974

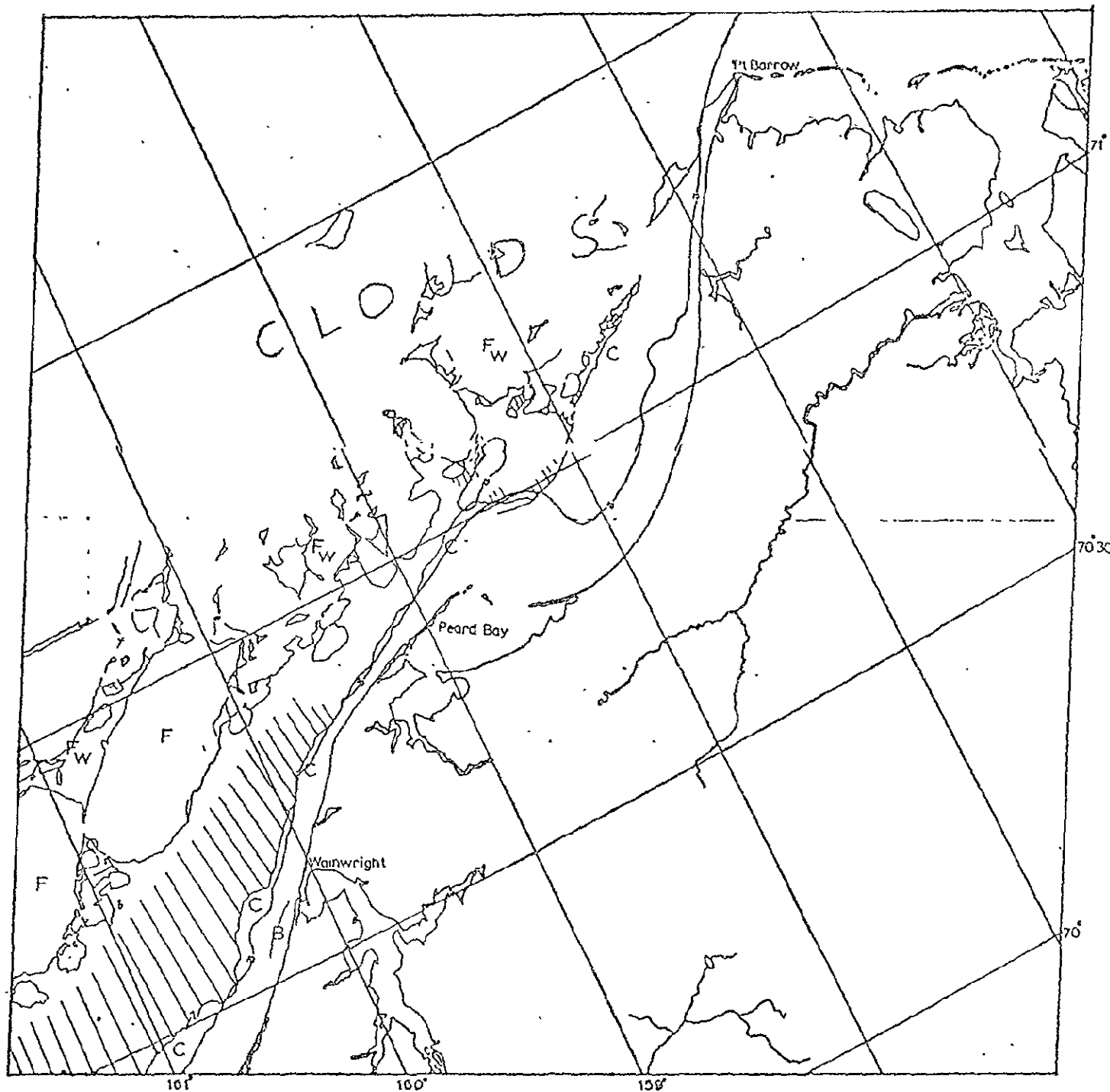




KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1673-21521-7  
 27 MAY 1974

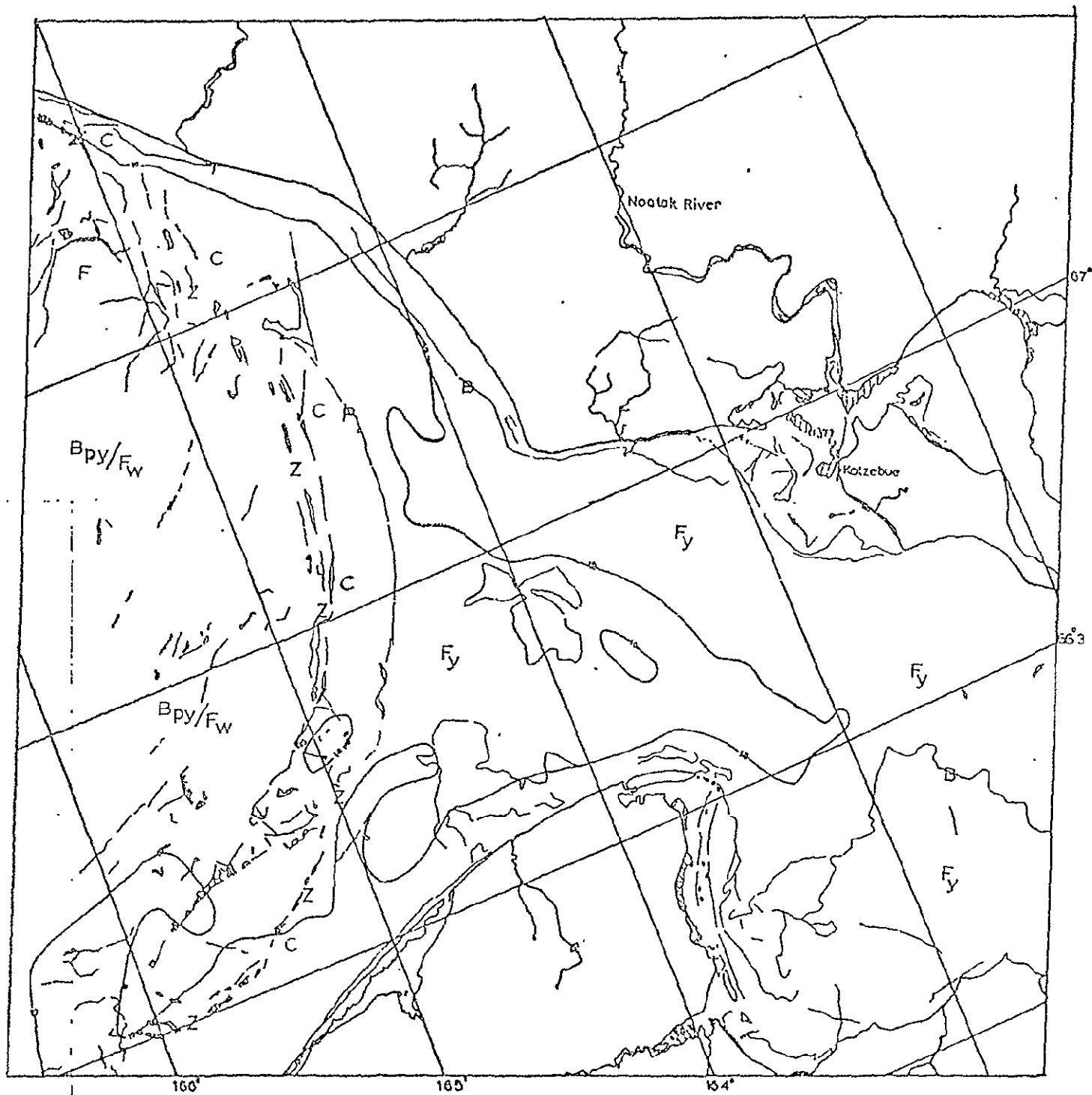


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1674-21561-7  
 28 MAY 1974

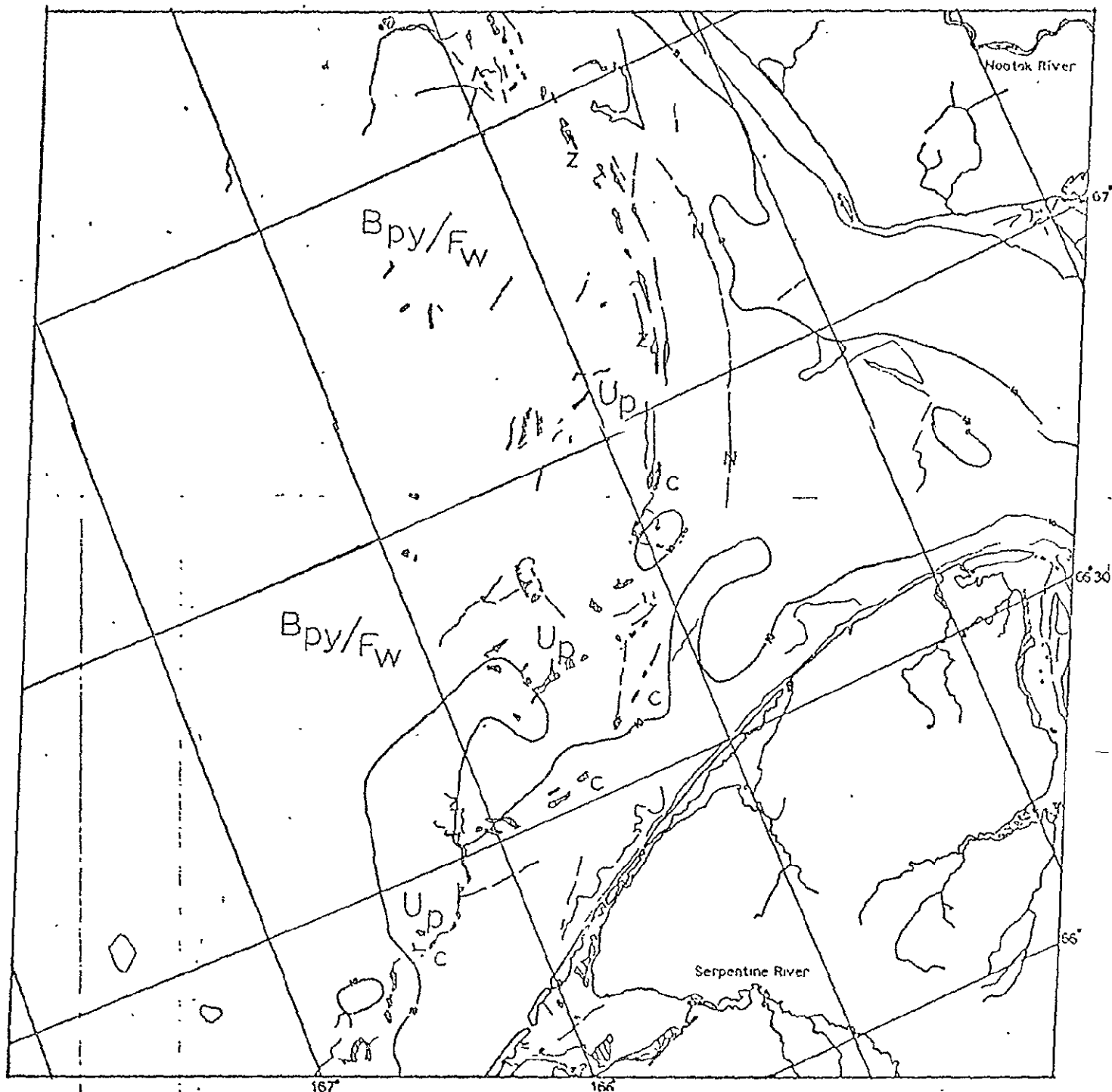
162



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

E-1874-21573-7  
28 MAY 1974

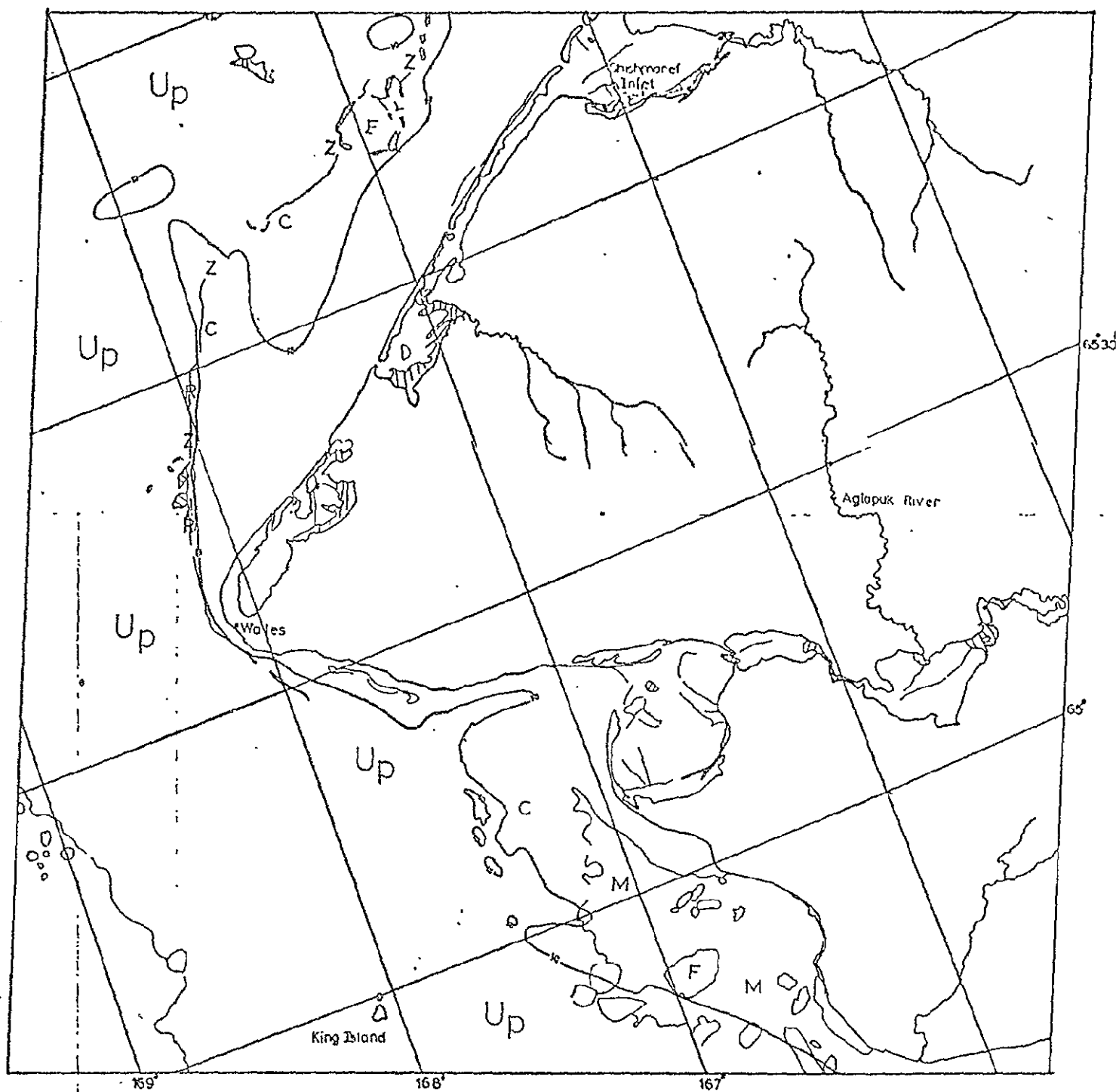
CHUKCHI SEA



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

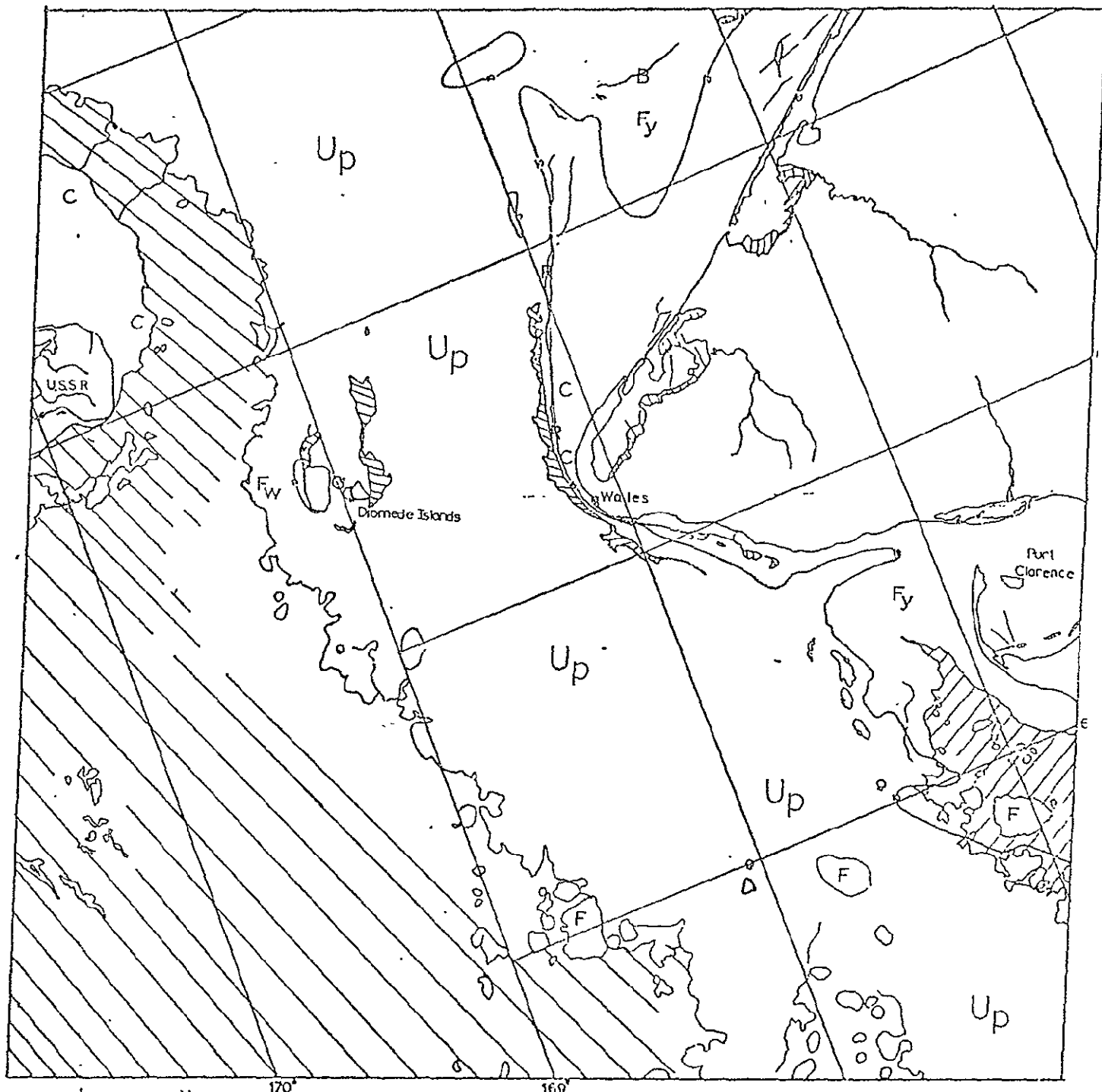
E-1675-22031-7  
29 MAY 1974



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

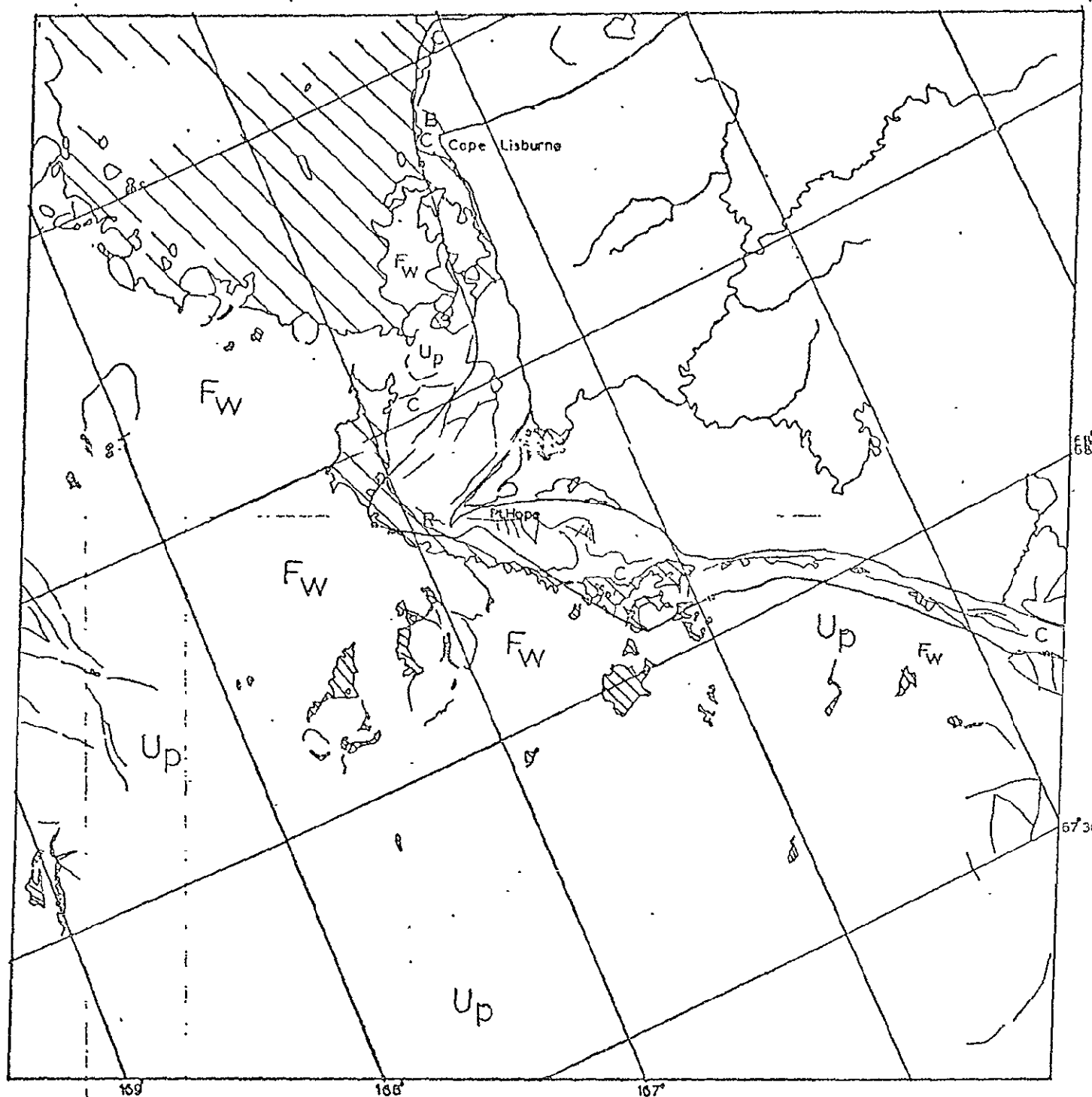
E-1675-220347  
 29 MAY 1974



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1676-22092-7  
 30 MAY 1971



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

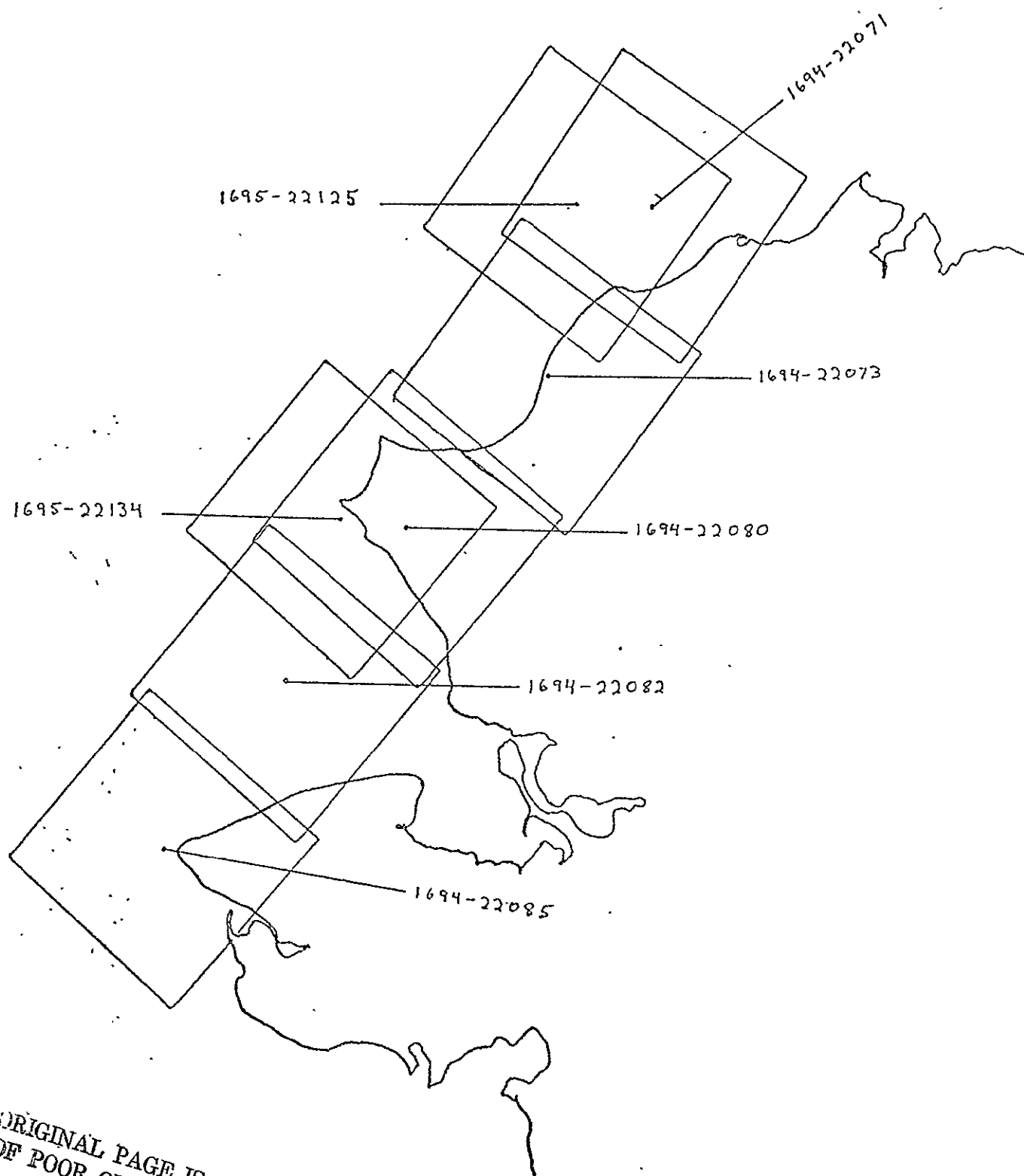
E-1677-22141-7  
 31 MAY 1974

CHUKCHI SEA

# CHUKCHI SEA

13-30 JUNE 1974

Cycle 1690-1707



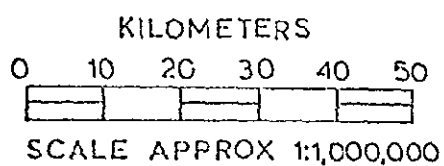
ORIGINAL PAGE IS  
OF POOR QUALITY



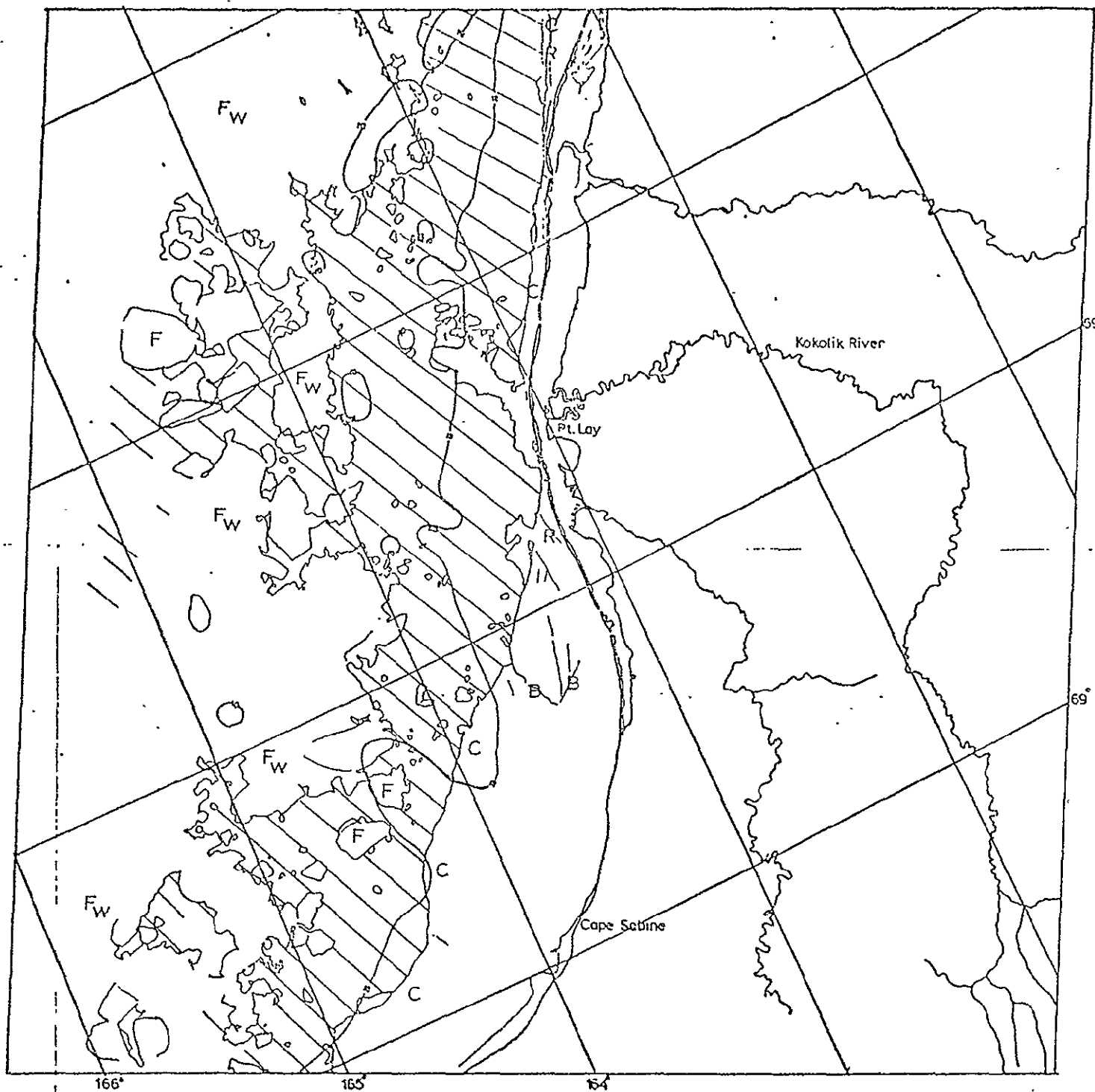
LANDSAT scenes 1694-22073 through 1695-22134

These scenes show the Chukchi coast on June 17-18, 1974, between Bering Strait and Point Franklin. The chief value of these images is to locate ice remaining in place and very likely to be well grounded, protected or both. Starting north from Bering Strait we find that ice formerly appearing to be grounded on shoals to the north has broken up and largely moved away. At Point Hope, some ice appears to remain along the shore to the southeast and on shoals to the immediate northwest. Only one small remnant of ice appears to remain stranded on shoals northwest of Cape Lisburne.

South of Icy Cape a small ribbon of ice remains along the coast widening at Blossom Shoals and narrowing again at Point Franklin.



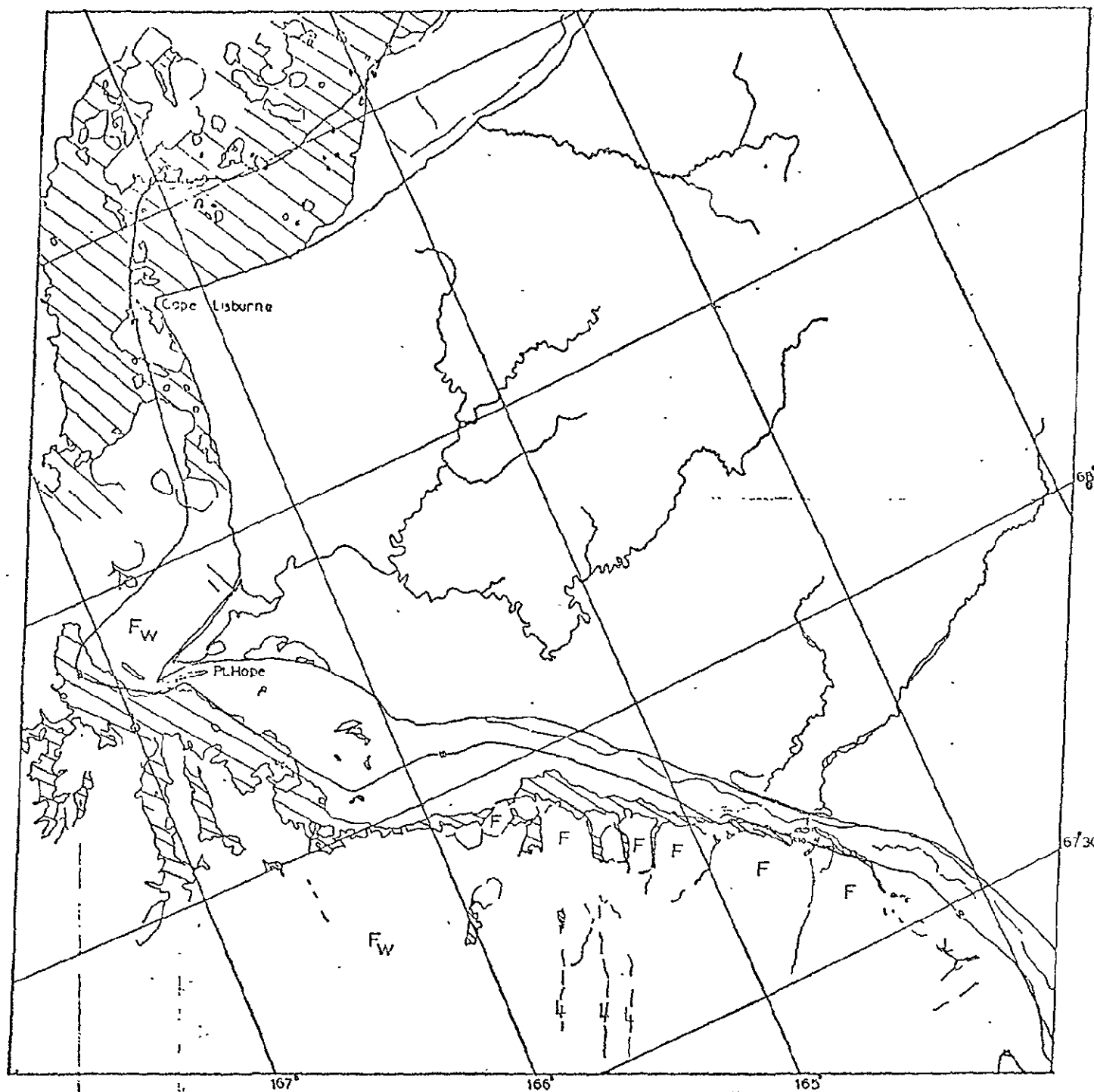
CHUKCHI SEA



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

E-169422073-7  
 17 JUNE 1974

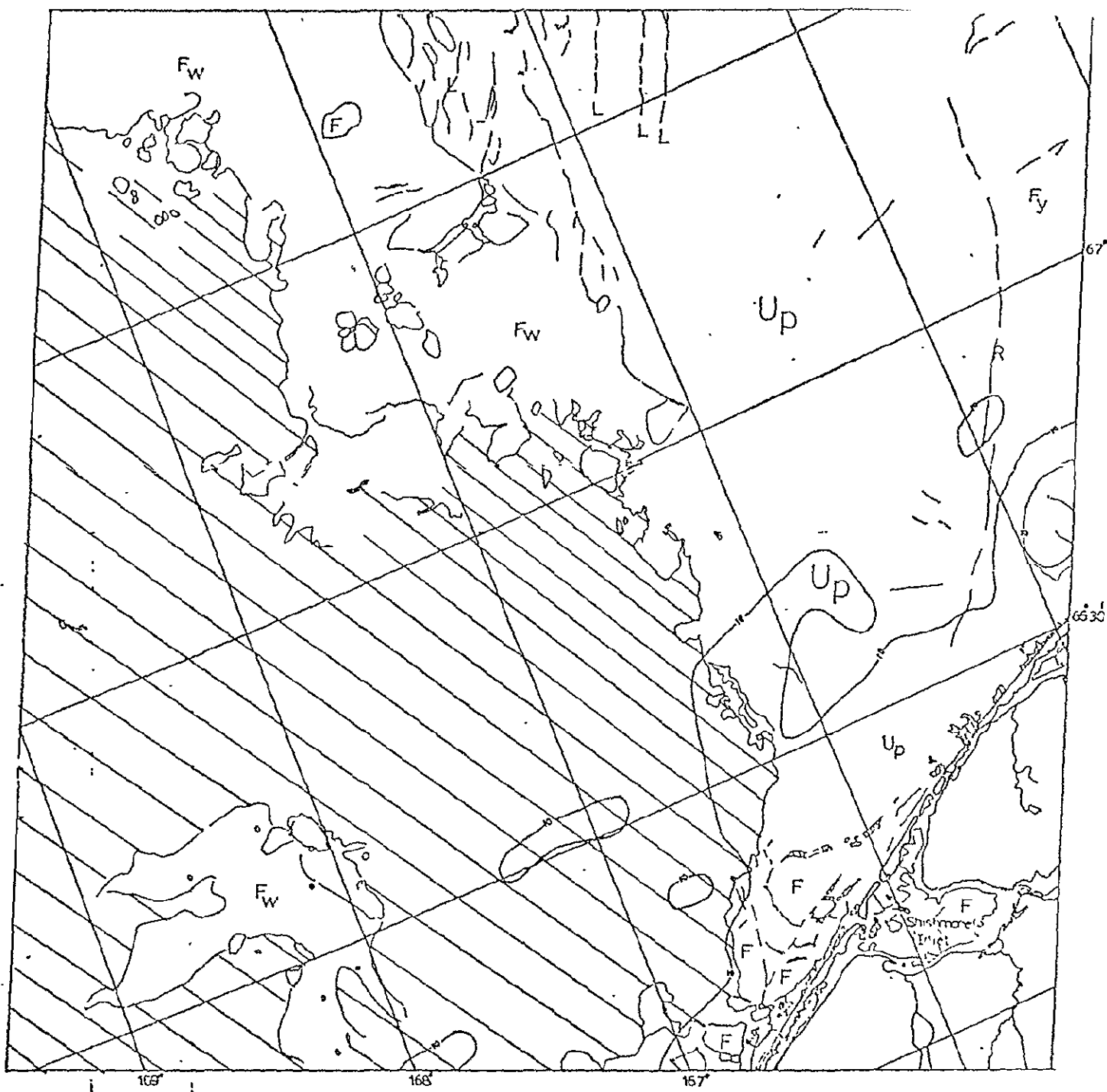
CHUKCHI SEA



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

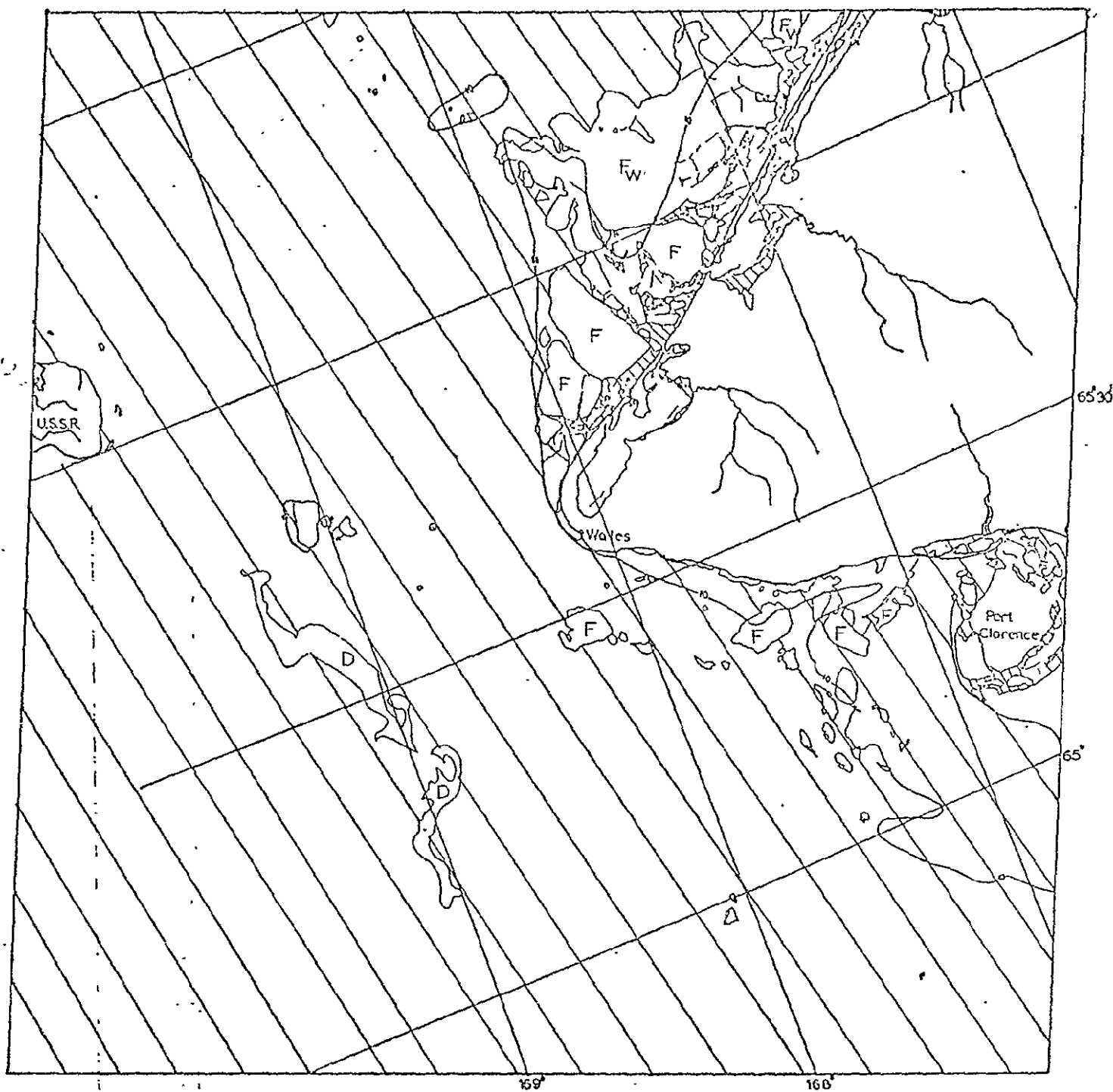
E-1694-22080-7  
17 JUNE 1974

CHUKCHI SEA



E-1694-22082-7  
17 JUNE 1974

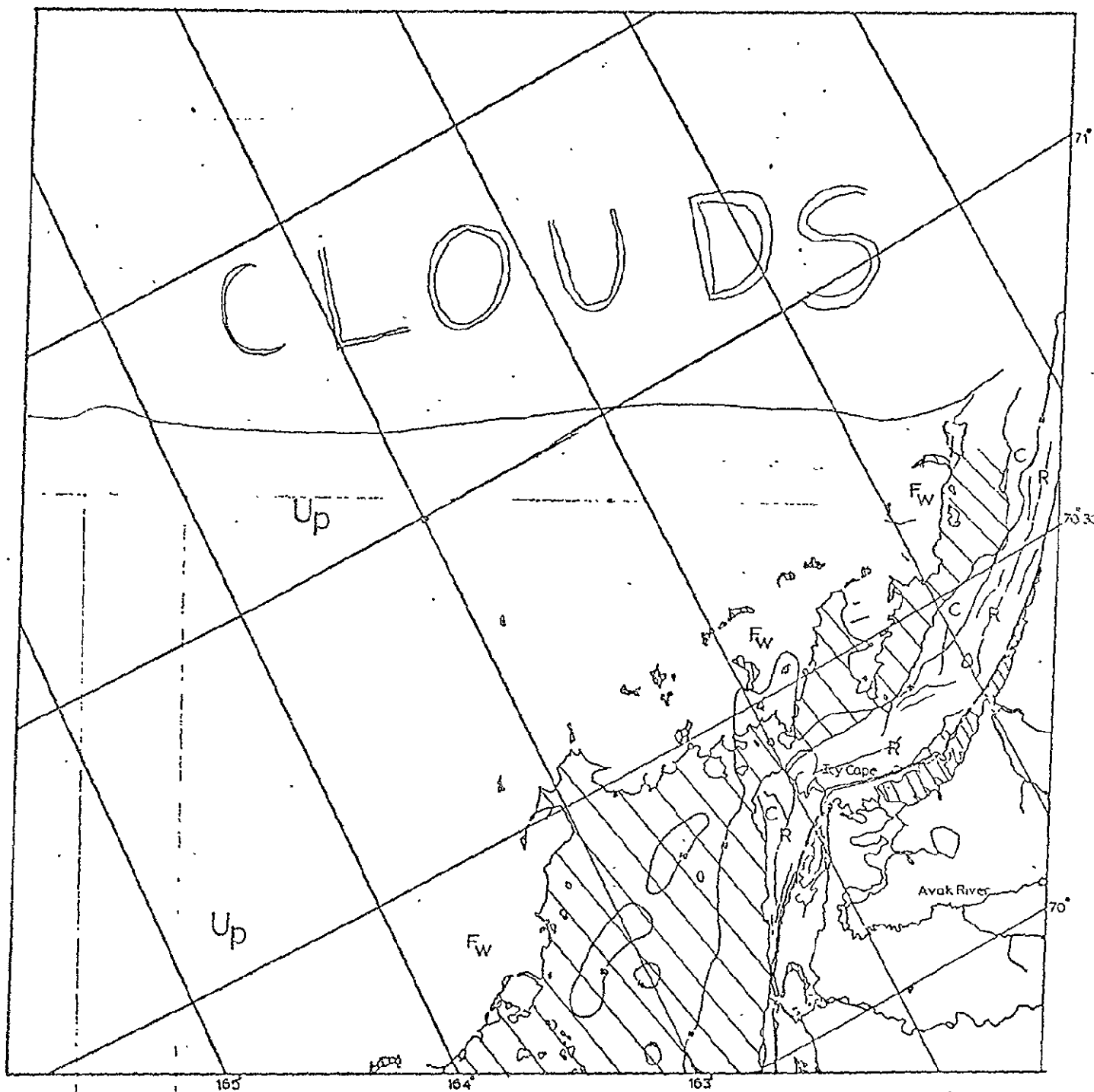
CHUKCHI SEA



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

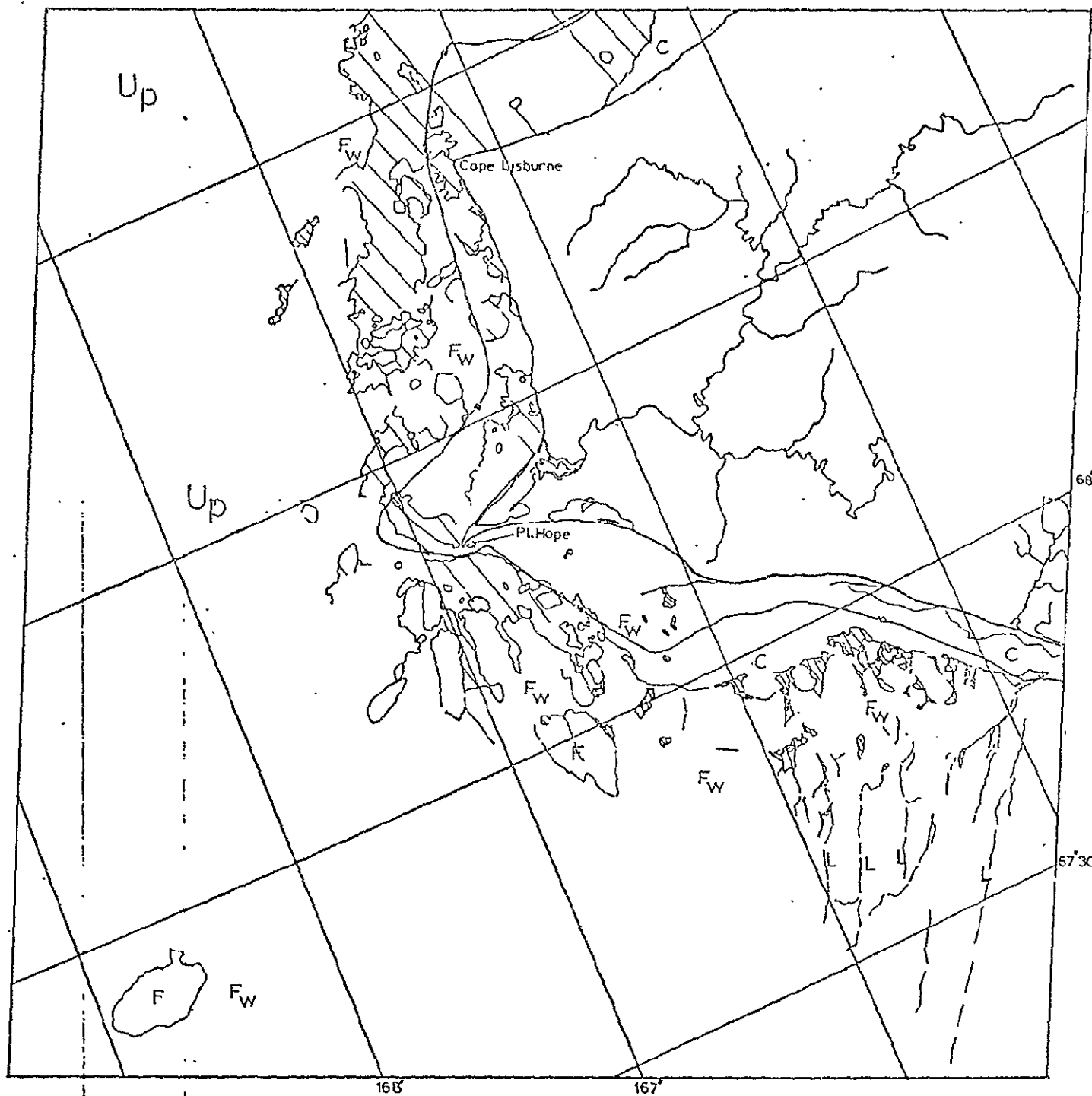
E-1694-22085-7  
17 JUNE 1974



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

E-1695-22125-7  
18 JUNE 1974

CHUKCHI SEA



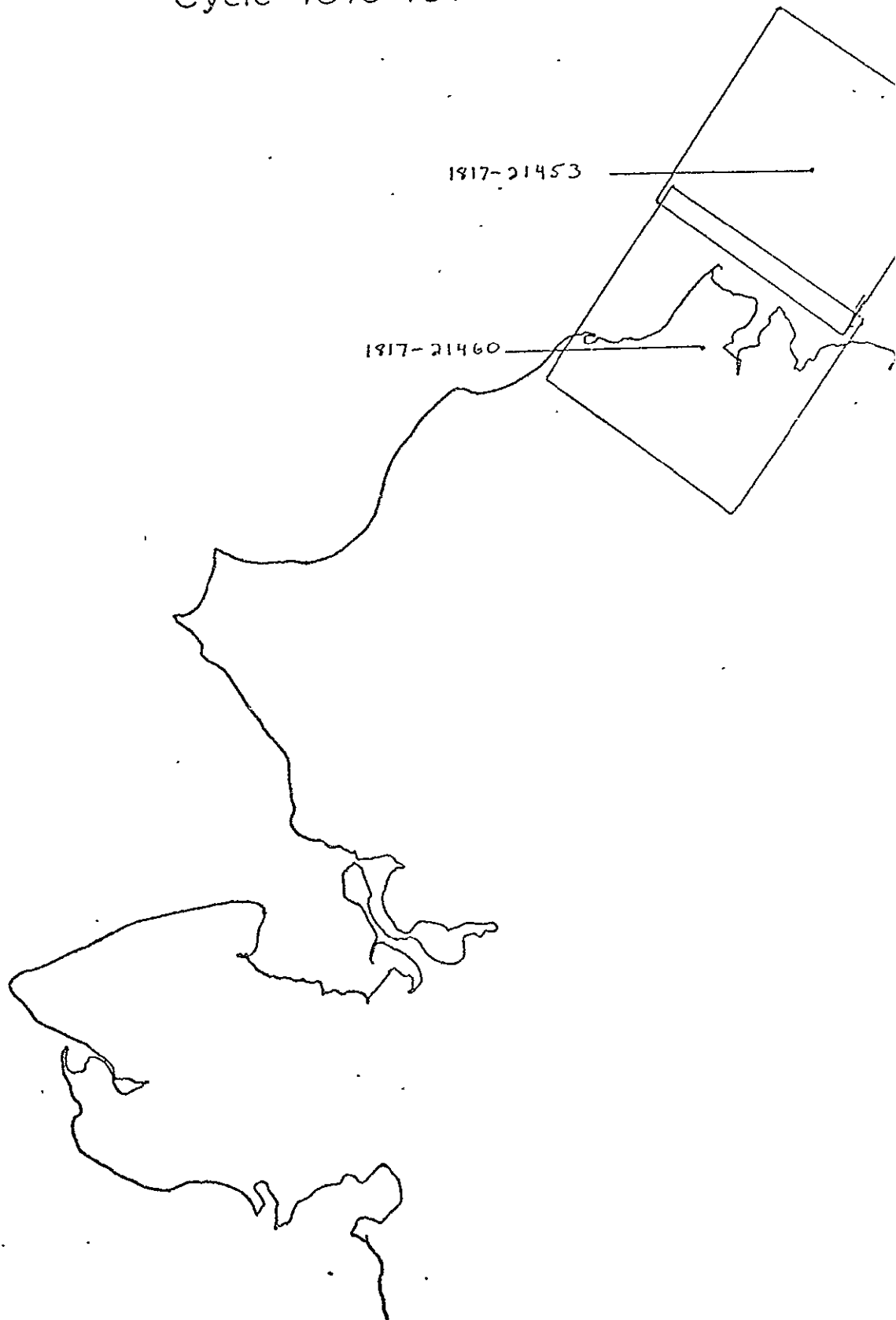
KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

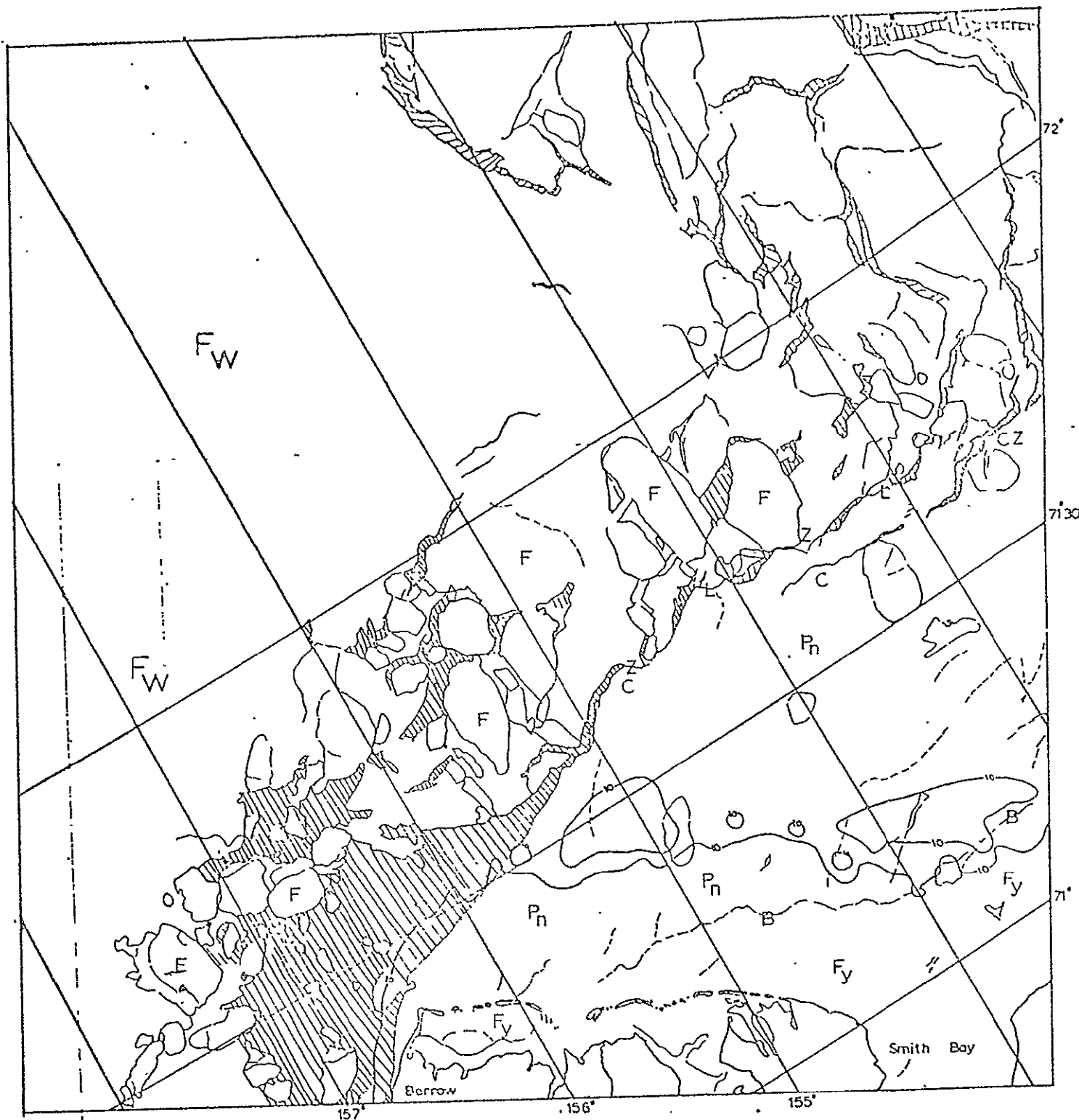
CHUKCHI SEA

E-1686-22134-7  
 18 JUNE 1974



CHUKCHI SEA  
17 OCTOBER-3 NOVEMBER  
1974  
Cycle 1816-1833



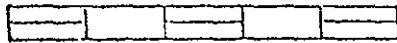


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1817-21453-7  
 18 October 1974

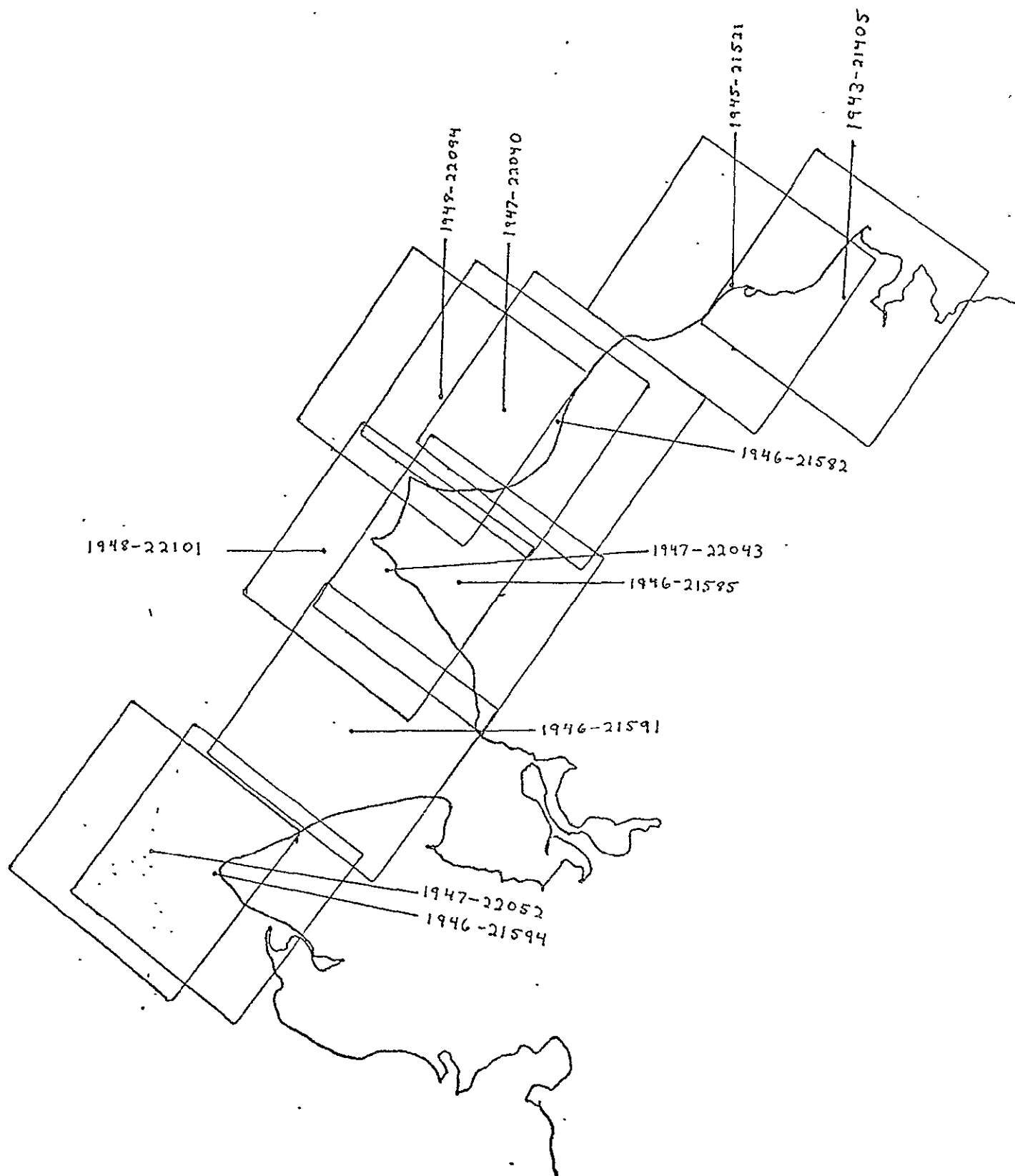


KILOMETERS  
 0 10 20 30 40 50  
  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1817-21460-7  
 18 October 1974

# Cycle 1942-1959



Scenes 1943-21405 through 1948-22101

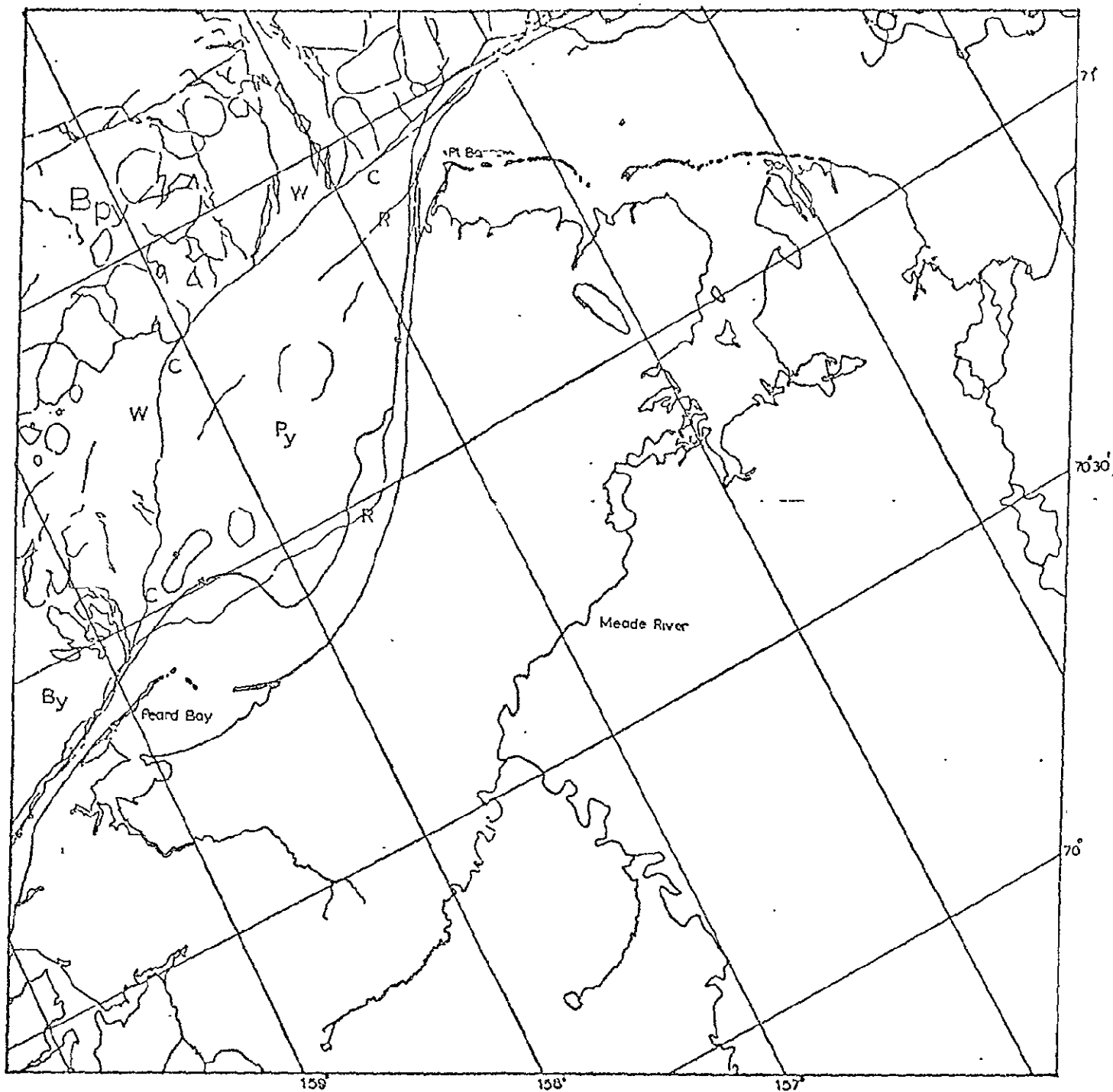
These scenes yield coverage of ice conditions along the Chukchi coast from Cape Prince of Wales to Barrow between February 20-28, 1975. It is apparent that the ice has been in motion with the formation of much new ice for some time. A broad zone of moving ice presents a shearing surface from Barrow to Bering Strait clearly illustrating in many places which ice is firmly fixed with respect to the shore.

Starting northward from Bering Strait, a large expanse of contiguous ice with some apparently grounded ridges is found to the north. Farther north, opposite Kotzebue Sound (and over deep water) this ice is considerably fractured, ending in a newly frozen polynya southeast of Point Hope. On the north side of the polynya, a narrow ribbon of contiguous ice is found next to the shore.

Northwest of Point Hope and Cape Lisburne large expanses of contiguous ice coincide with shoals some distance from shore. Some evidence of ridges can be found on the seaward side of these areas of ice.

Farther north, the edge of contiguous ice appears to have been formed by the breaking away of ice moving seaward. However, large ridges can be seen on Blossom Shoal, from Point Franklin to the south, and off Barrow within the apron of contiguous ice.

ORIGINAL PAGE IS  
OF POOR QUALITY

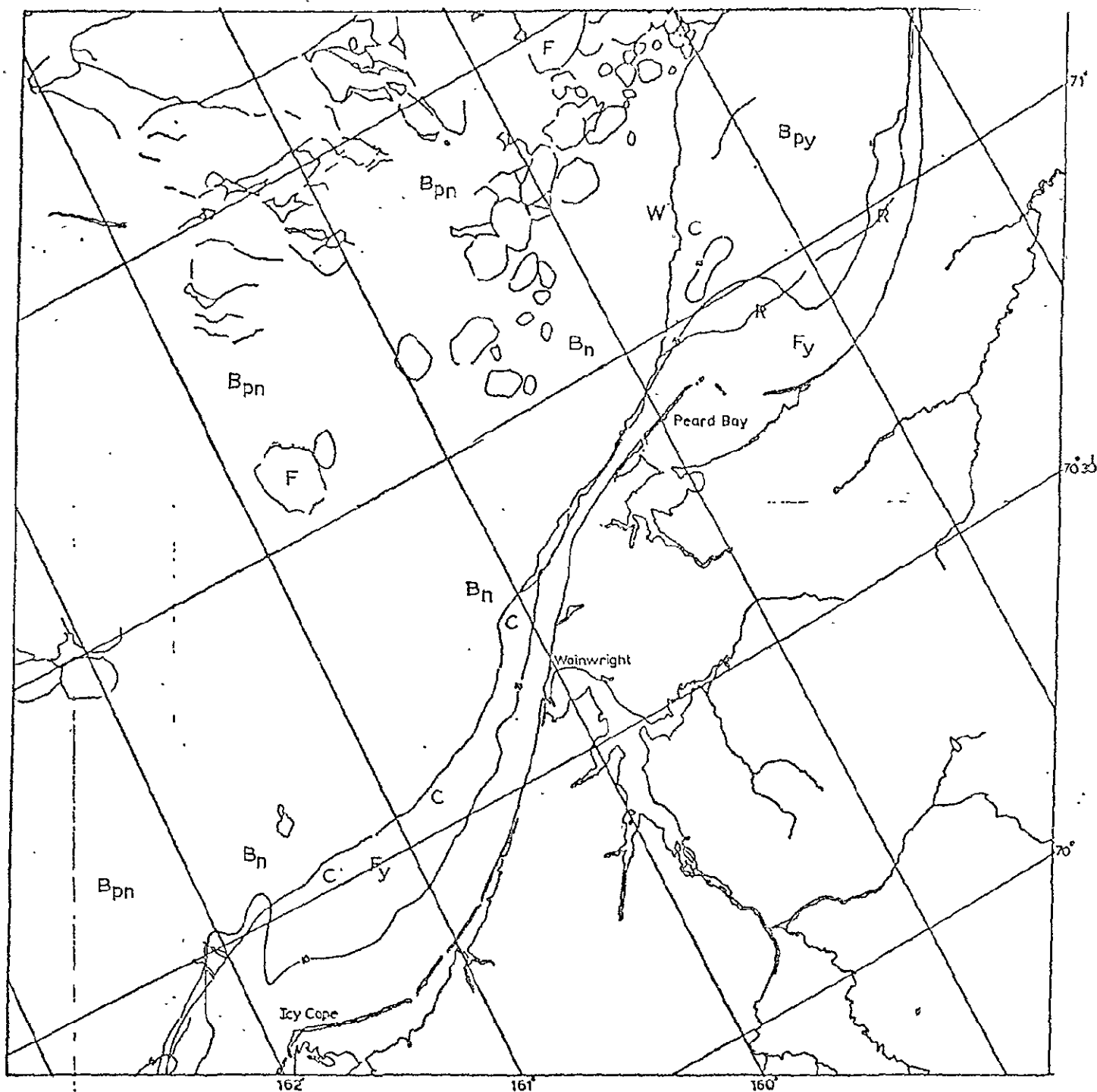


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1943-21405-7  
 21 FEB. 1975

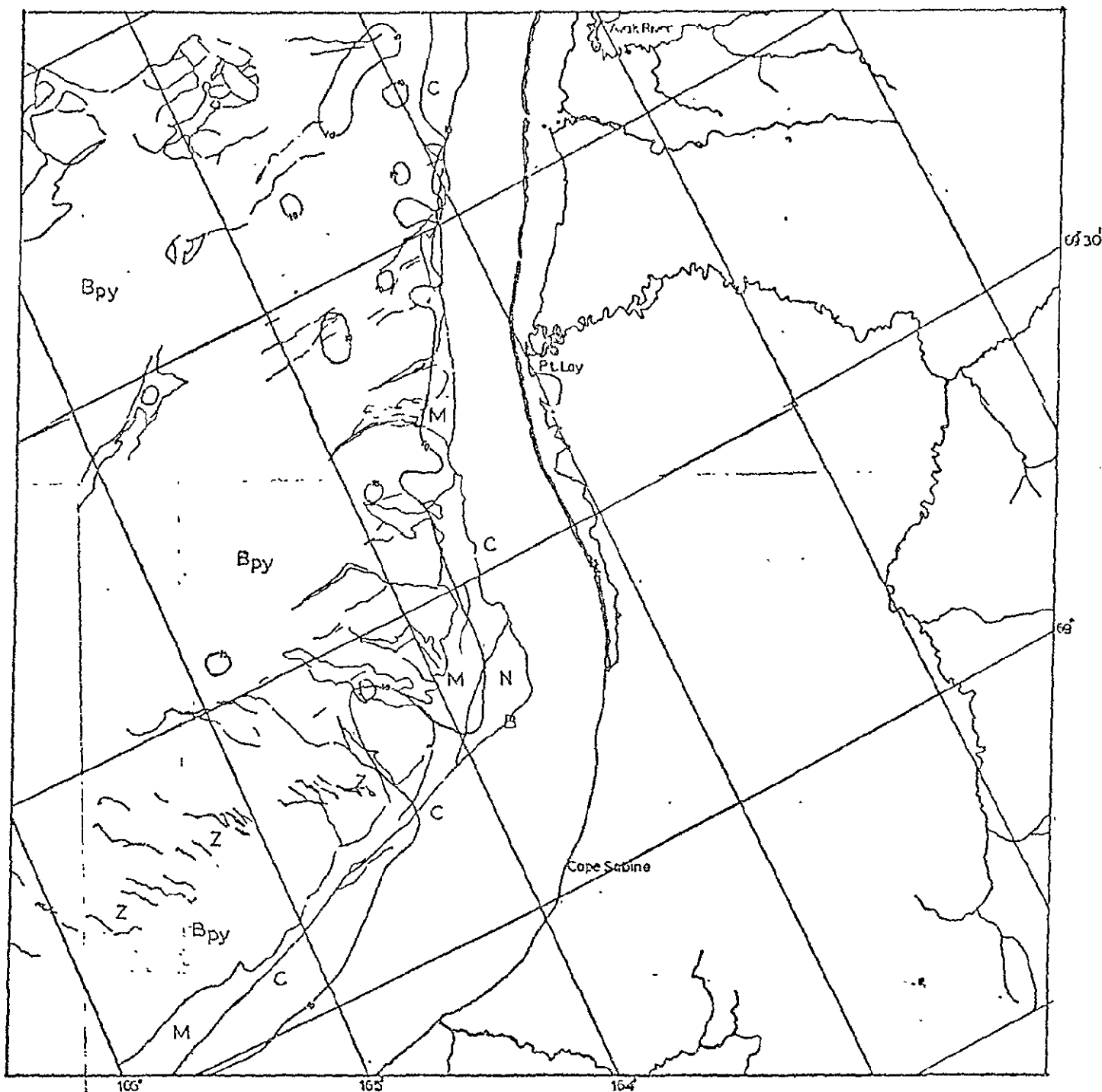
182

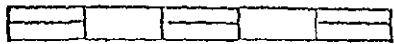


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1945-21521-7  
 23 FEB. 1975

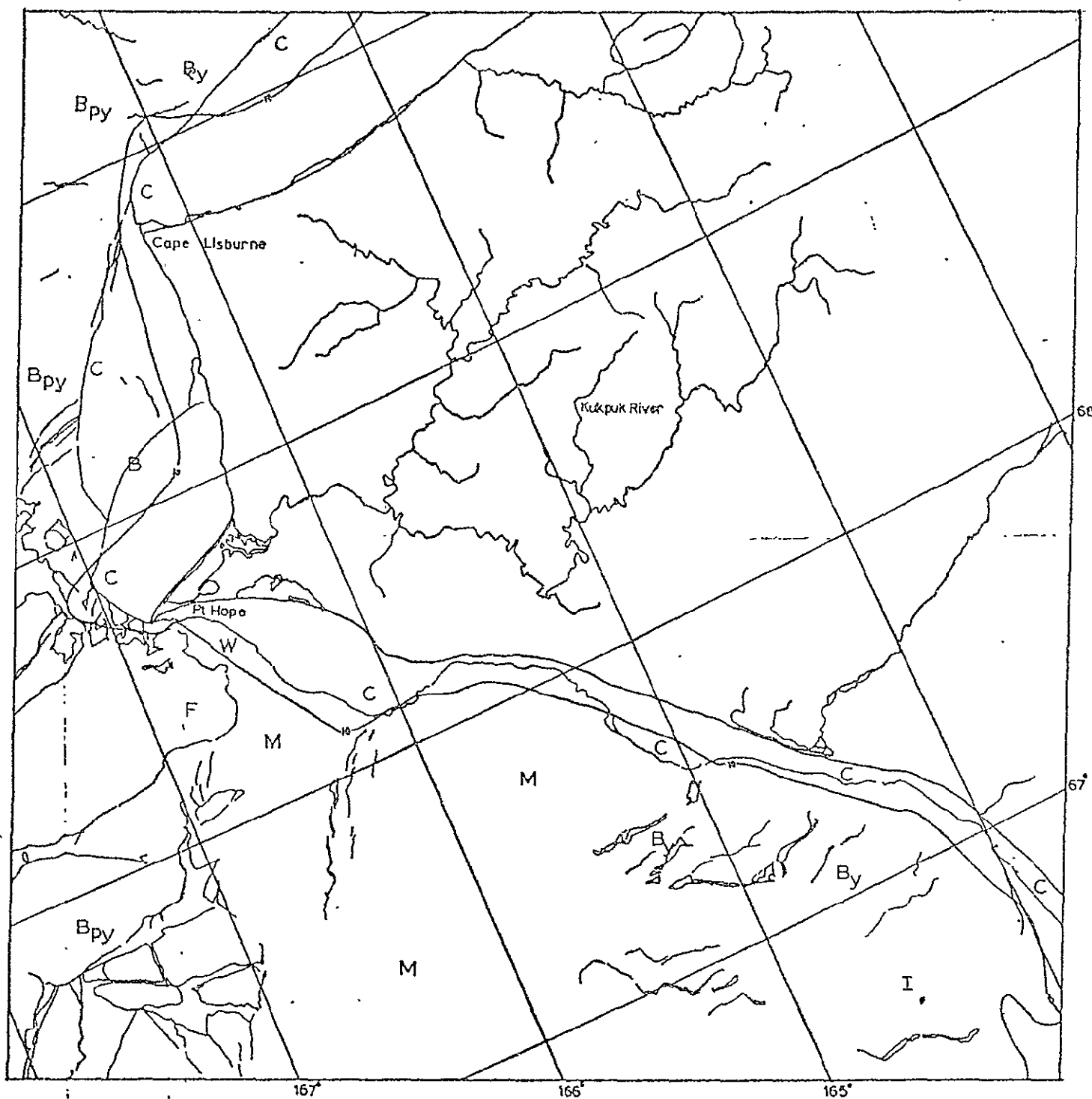


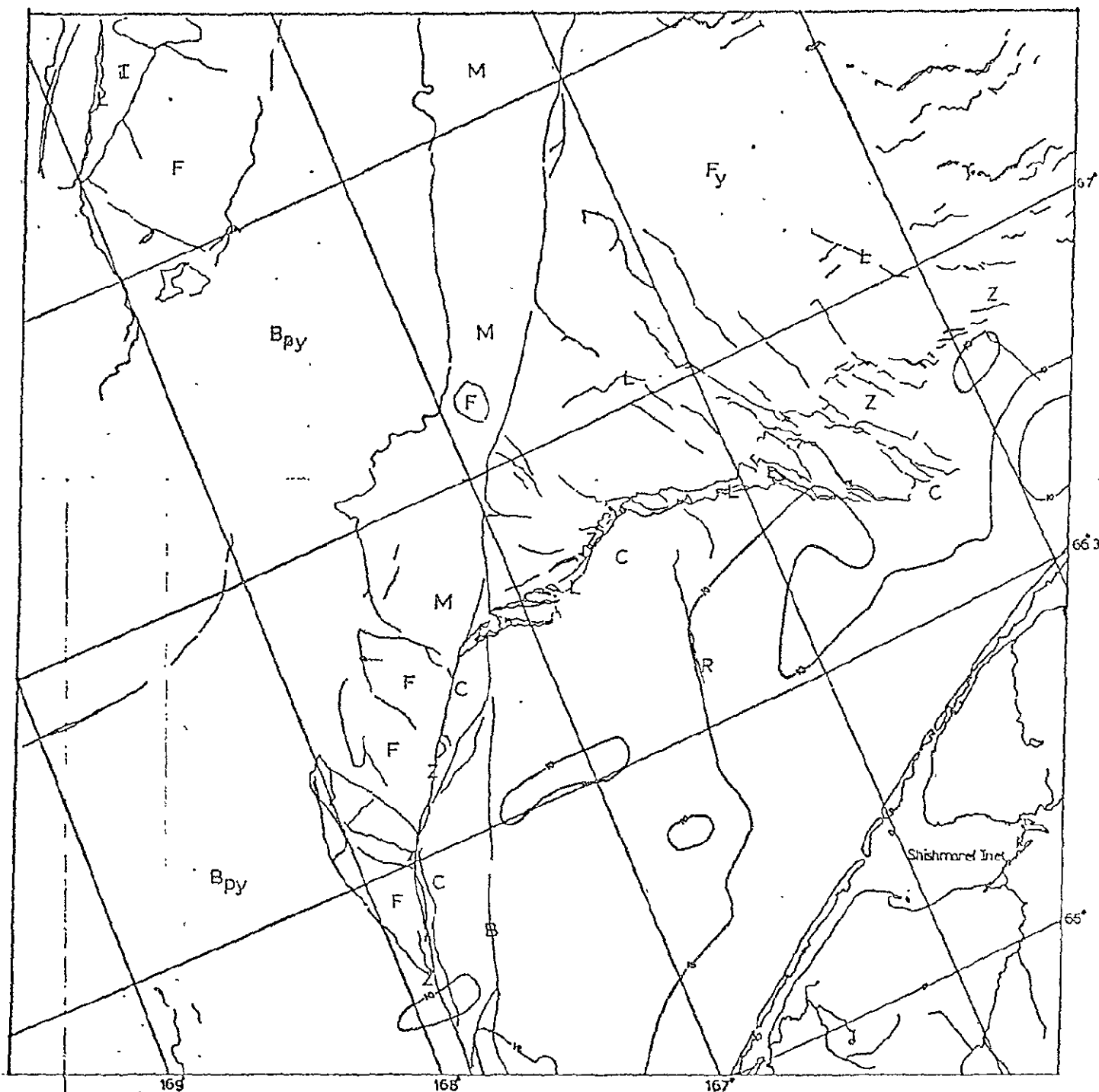
KILOMETERS  
 0 10 20 30 40 50  
  
 SCALE APPROX 1:1,000,000

E-1946-21582-7  
 24 FEB 1975

CHUKCHI SEA



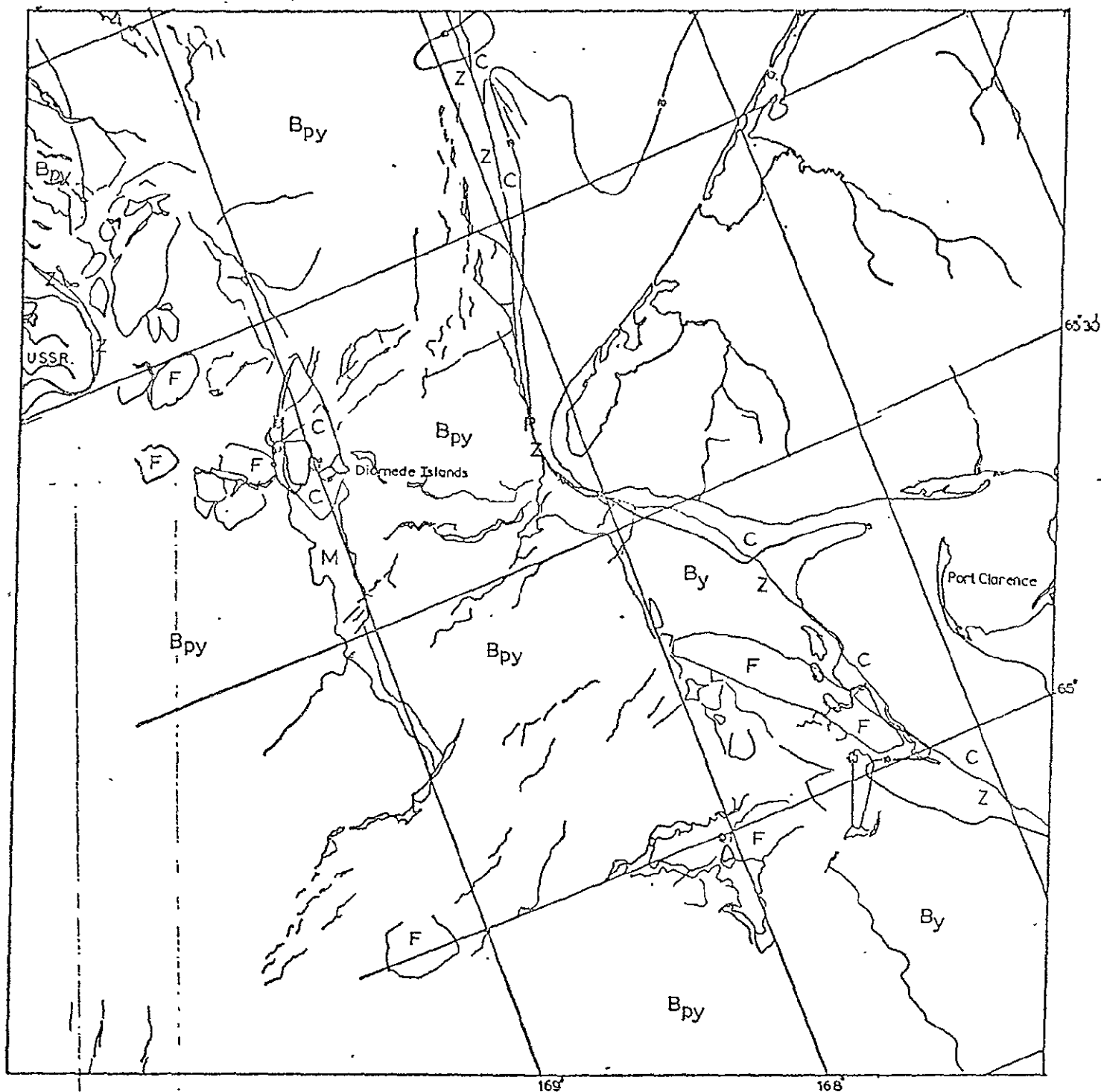




KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

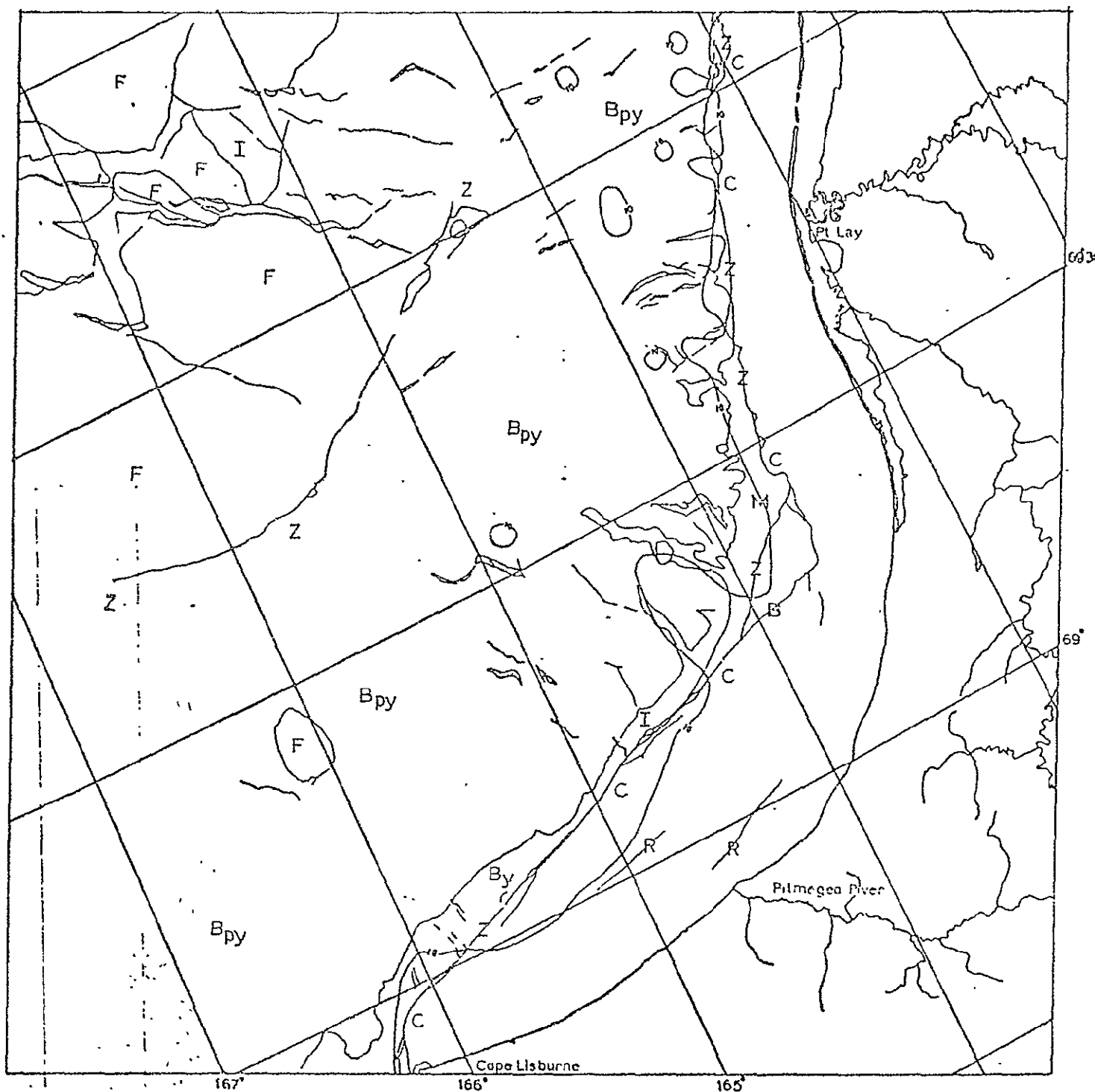
E-1946-21591-7  
 24 FEB. 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

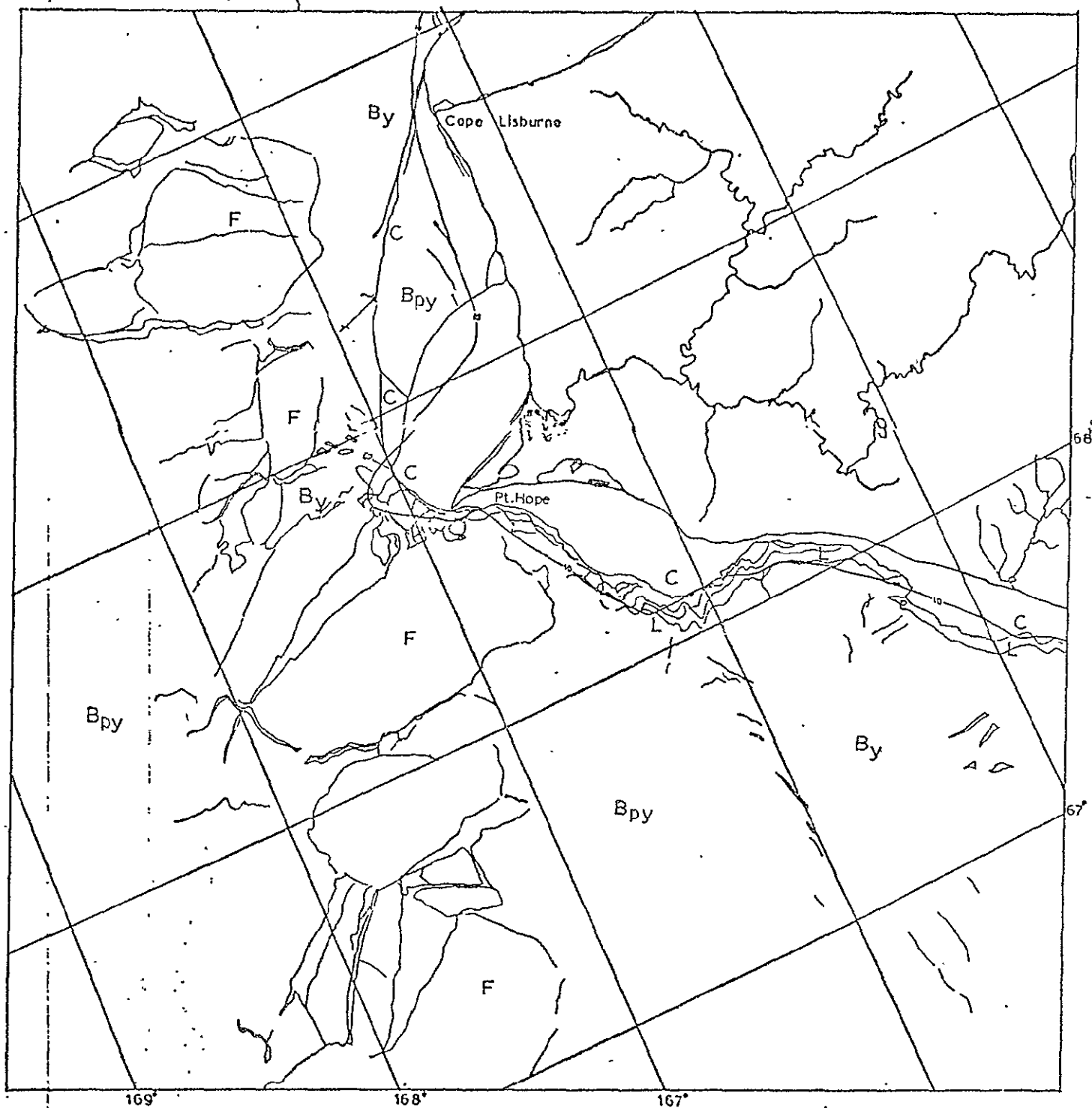
E-1946-21594-7  
24 FEB. 1975



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

E1947-22040-7  
 25 FEB. 1975

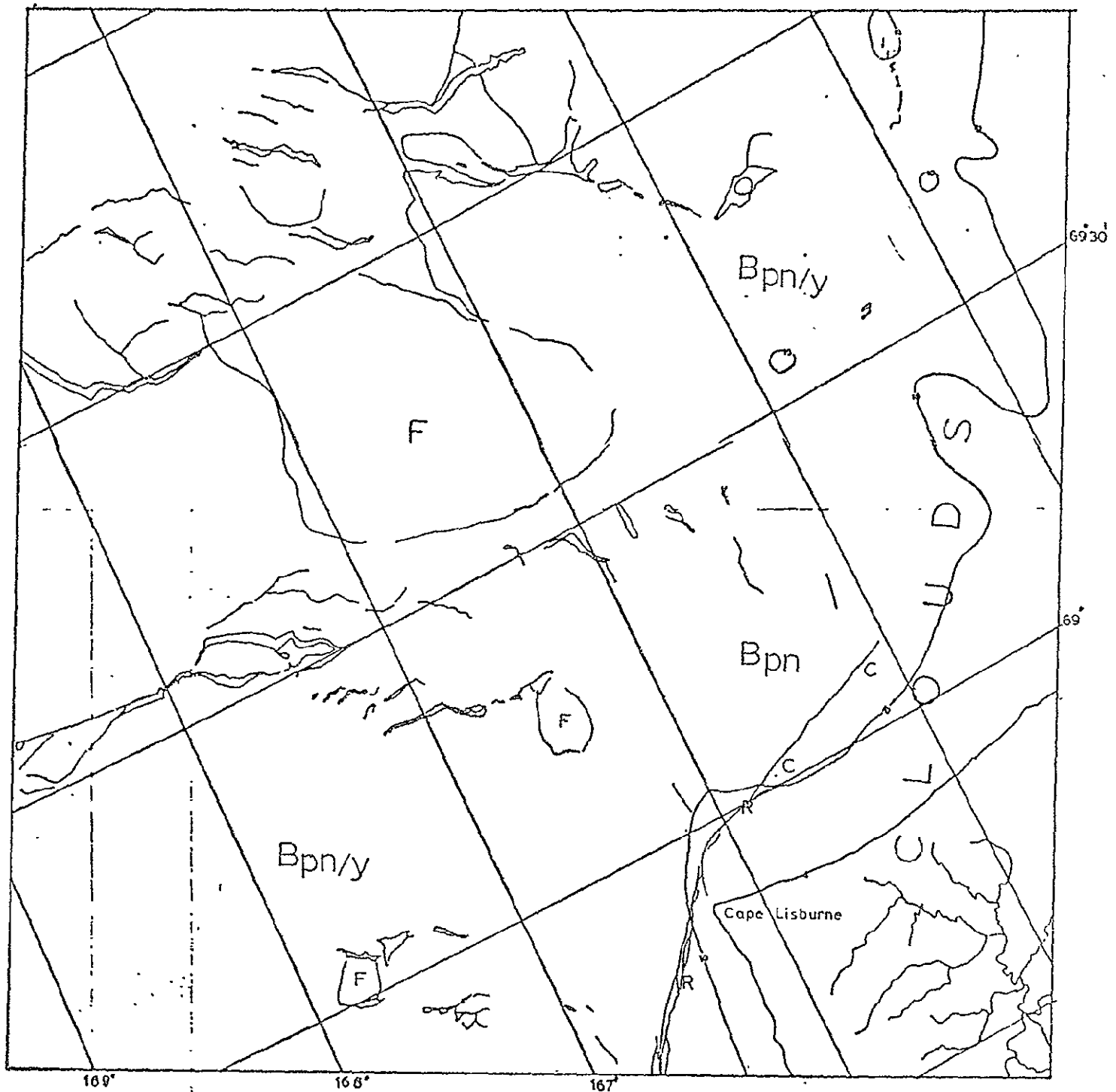
CHUKCHI SEA



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

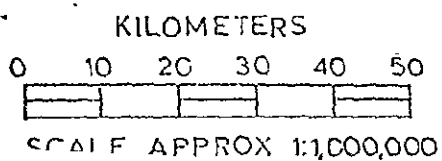
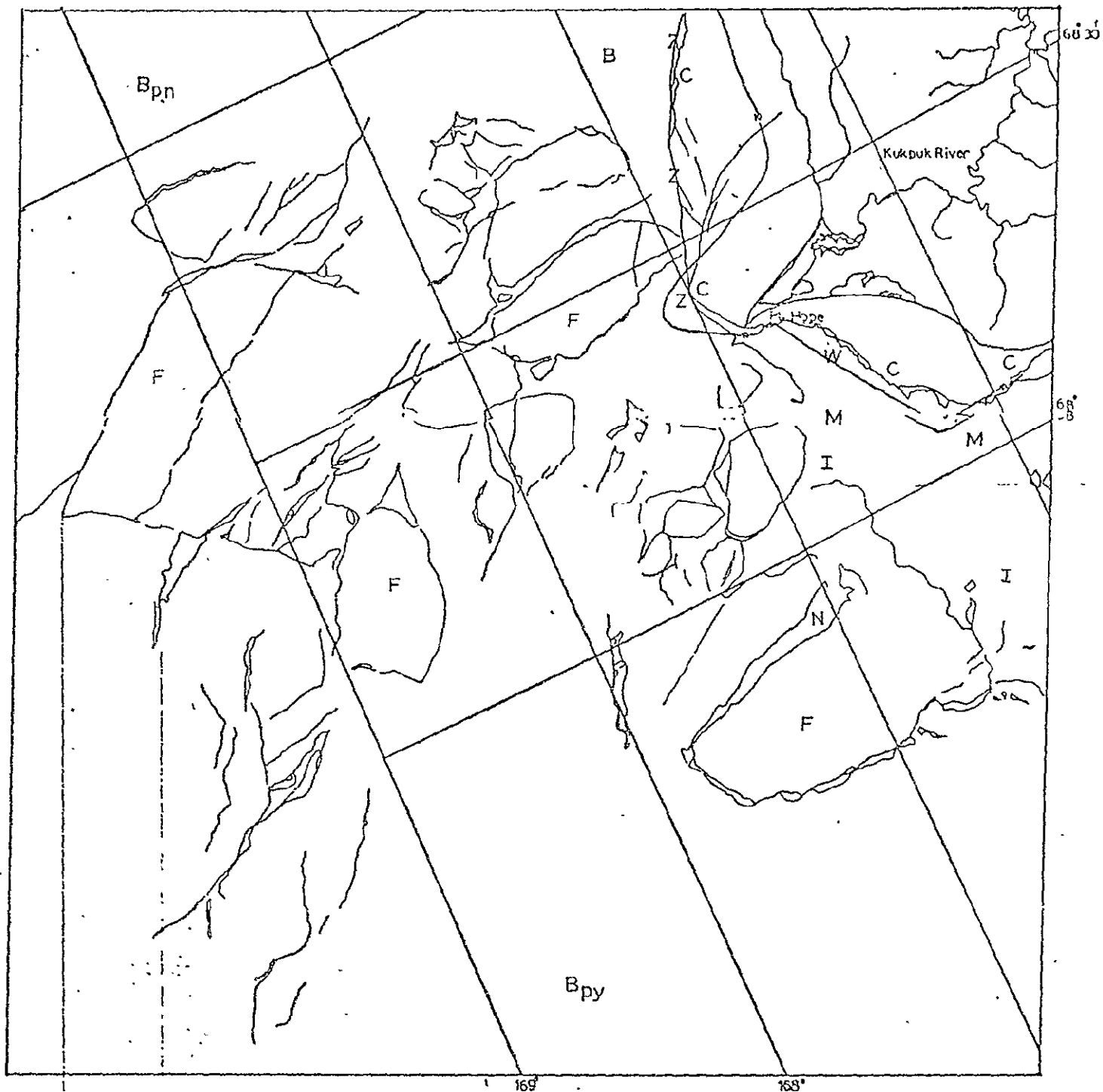
E-1947-22043-7  
25 FEB. 1975



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

E-1948-22094-7  
 26 FEB. 1975

CHUKCHI SEA



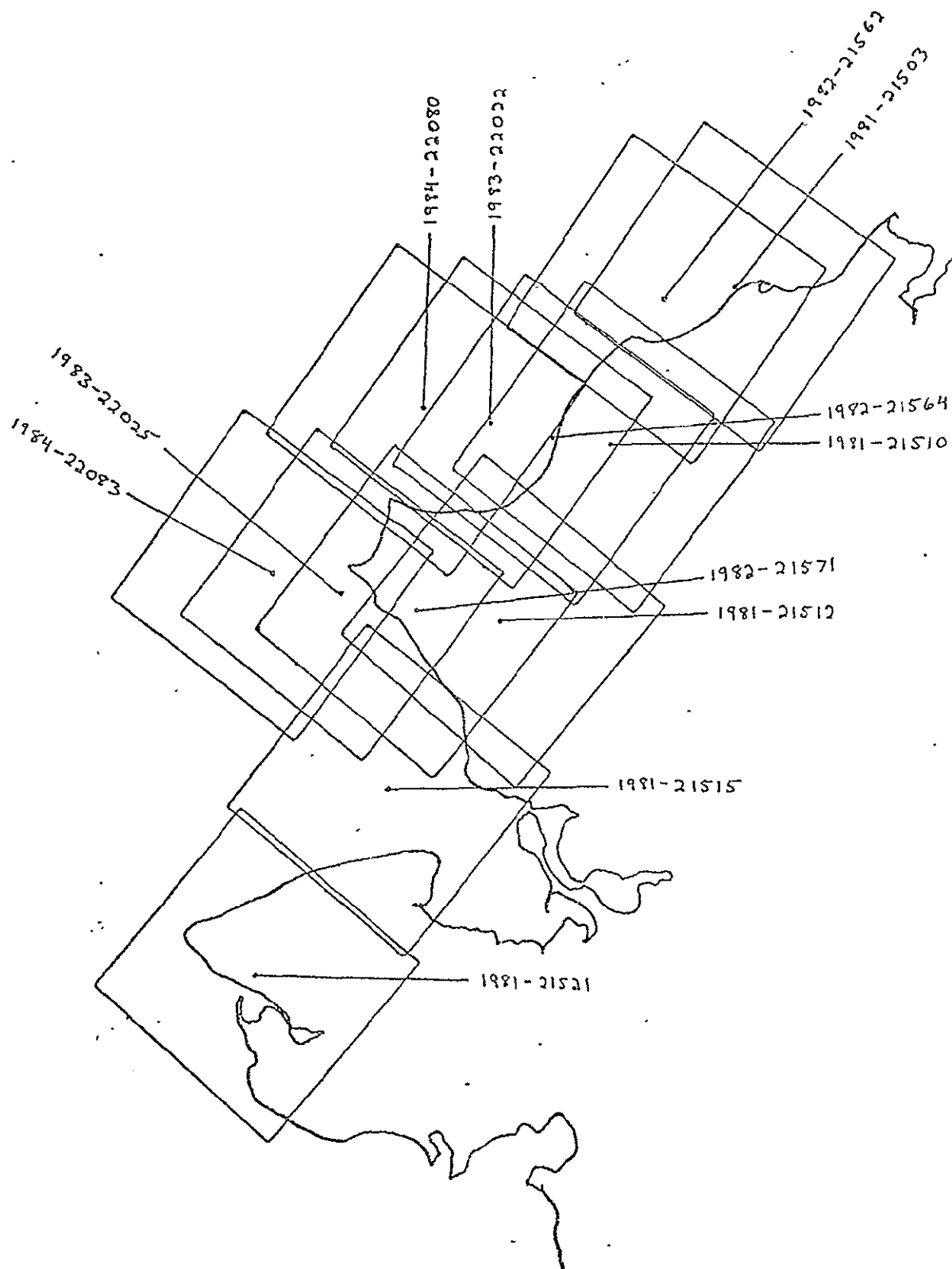
E-1948-22101-7.  
 26 FEB. 1975

CHUKCHI SEA

# CHUKCHI SEA

28 MARCH-14 APRIL 1975

Cycle 1978-1995

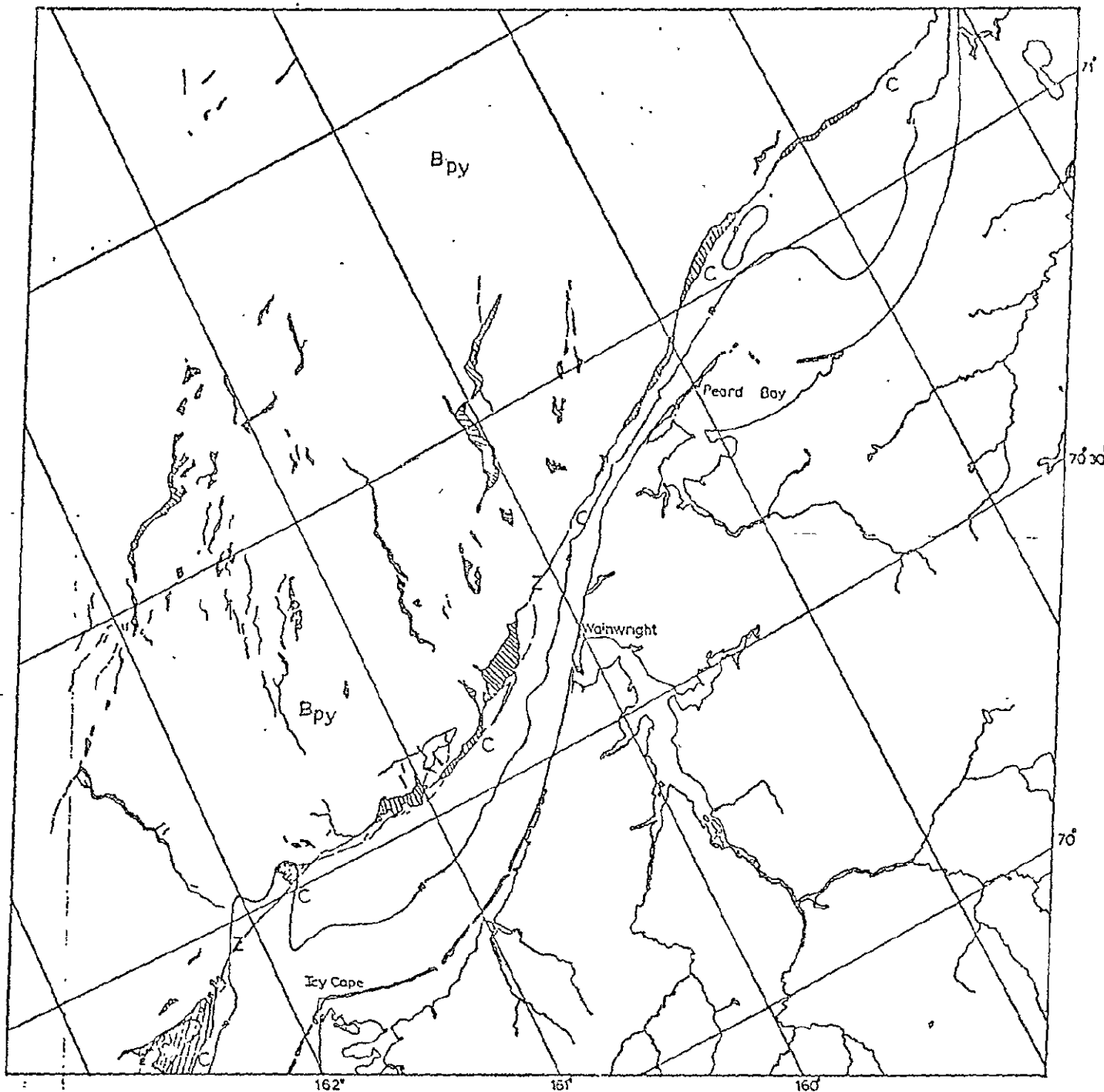




Scenes 1981-21503 through 2080-22151

These scenes show the Chukchi coast for the period March 31 through April 12, 1975. As in the previous cycle of imagery mapped the ice appears to have been in motion for some time. The active edge of ice appears to have changed little since the previous cycle of images with the exception of outer Kotzebue sound where additional ice has become mobilized. Large expanses of apparently grounded ice can be found on shoals north of Cape Prince of Wales, Point Hope, and on Blossom Shoals. Indentations in contiguous ice shoreward of the 10-fathom contour can be found southeast of Point Hope, south of Cape Lisburne and south of Icy Cape, following the pattern established earlier.

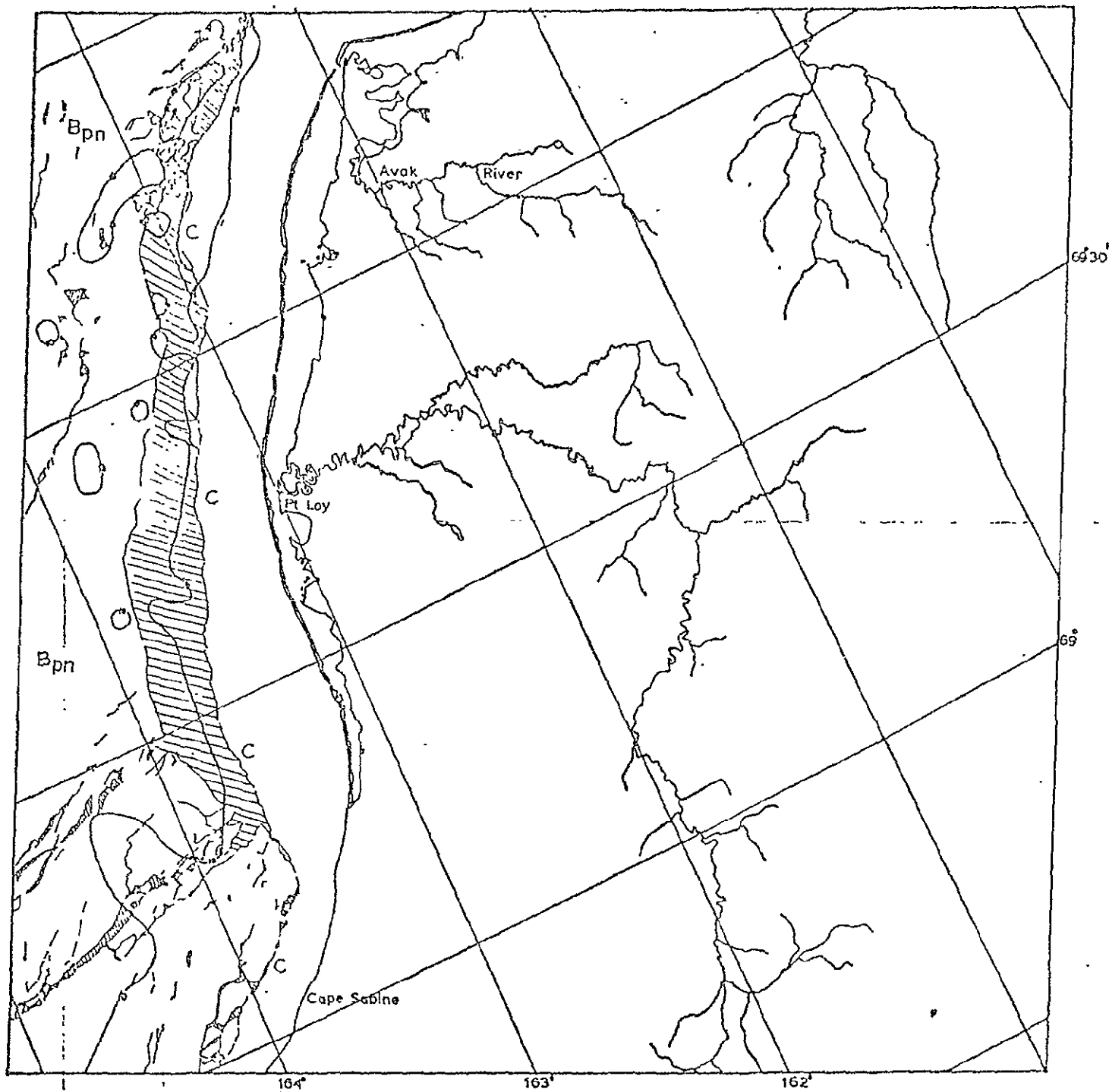
ORIGINAL PAGE IS  
OF POOR QUALITY



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1981-21503-7  
31 MARCH 1975



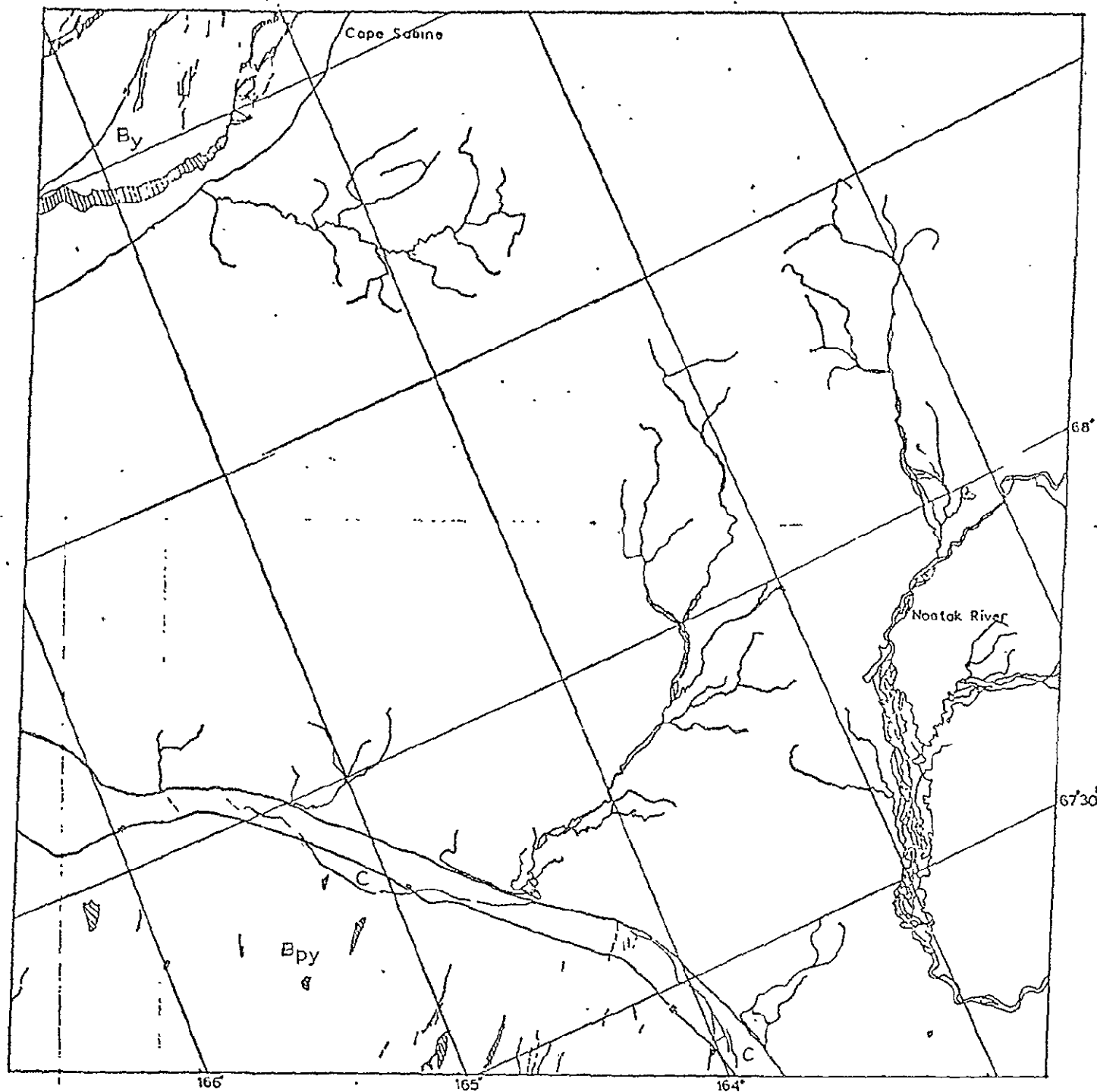
0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1981-21510-7  
 31 MARCH 1975

C.3

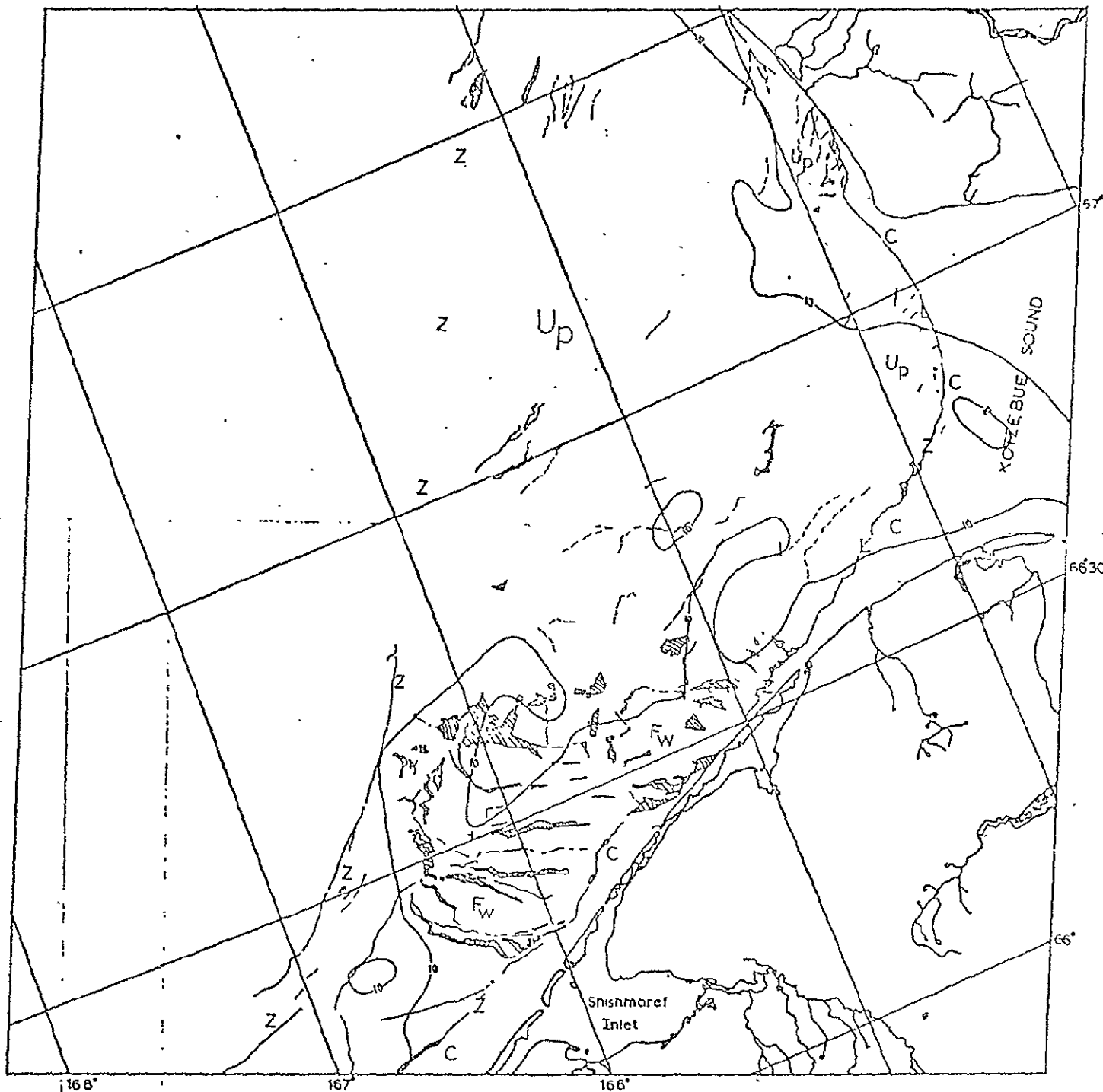
195



E-1981-21512-7

31 MARCH 1975

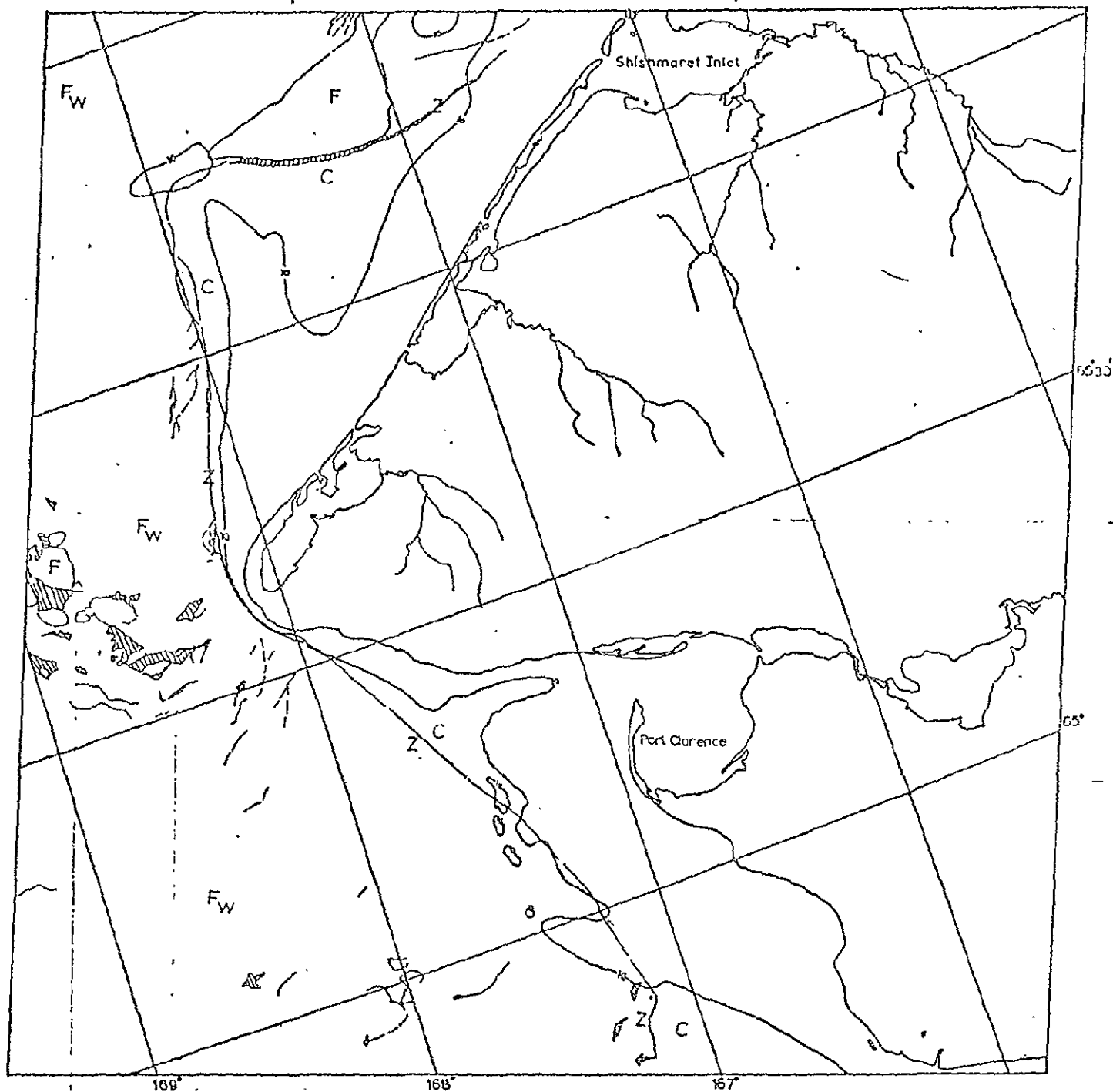
CHUKCHI SEA



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

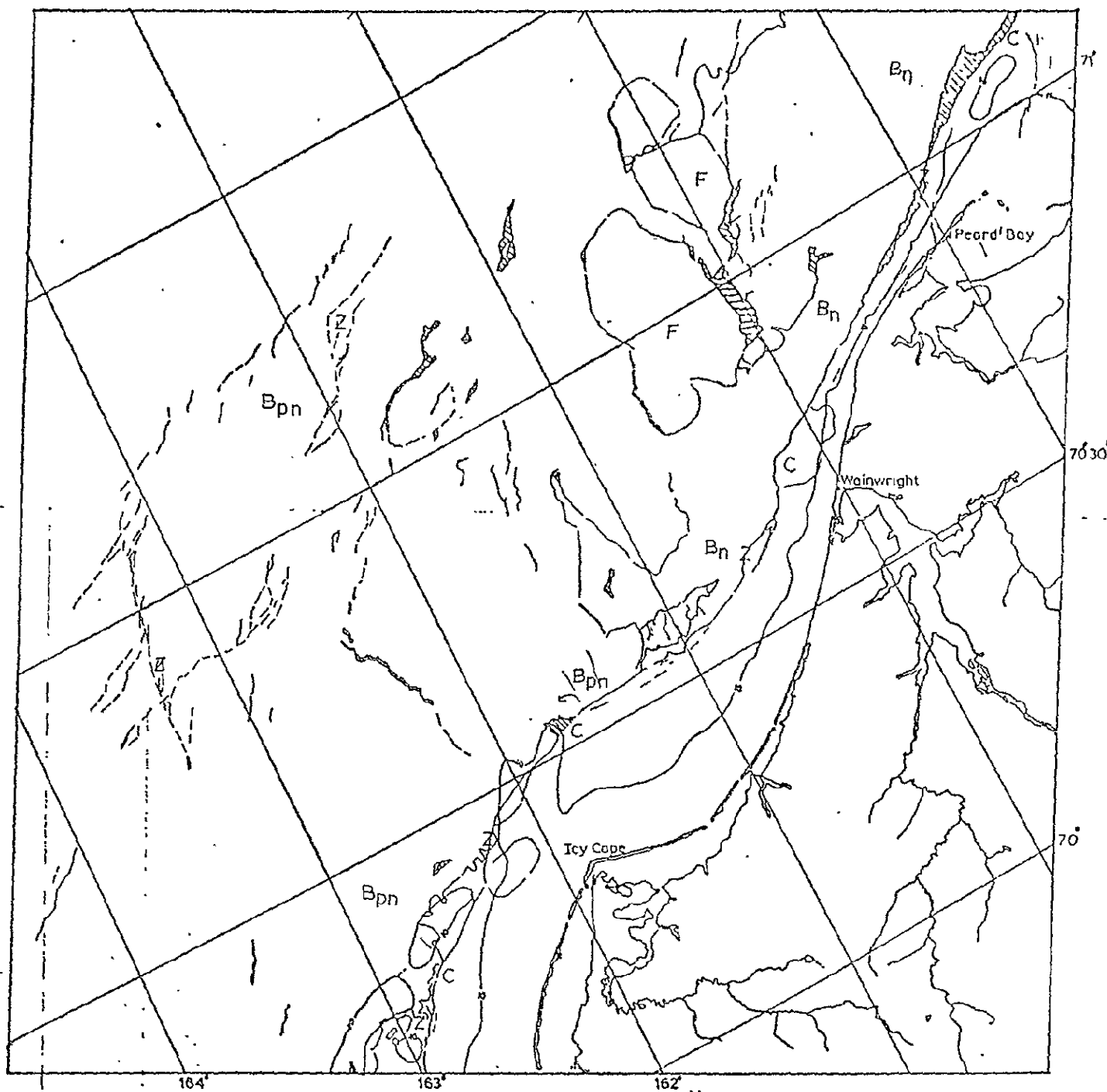
E-1981-21515-7  
31 MARCH 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

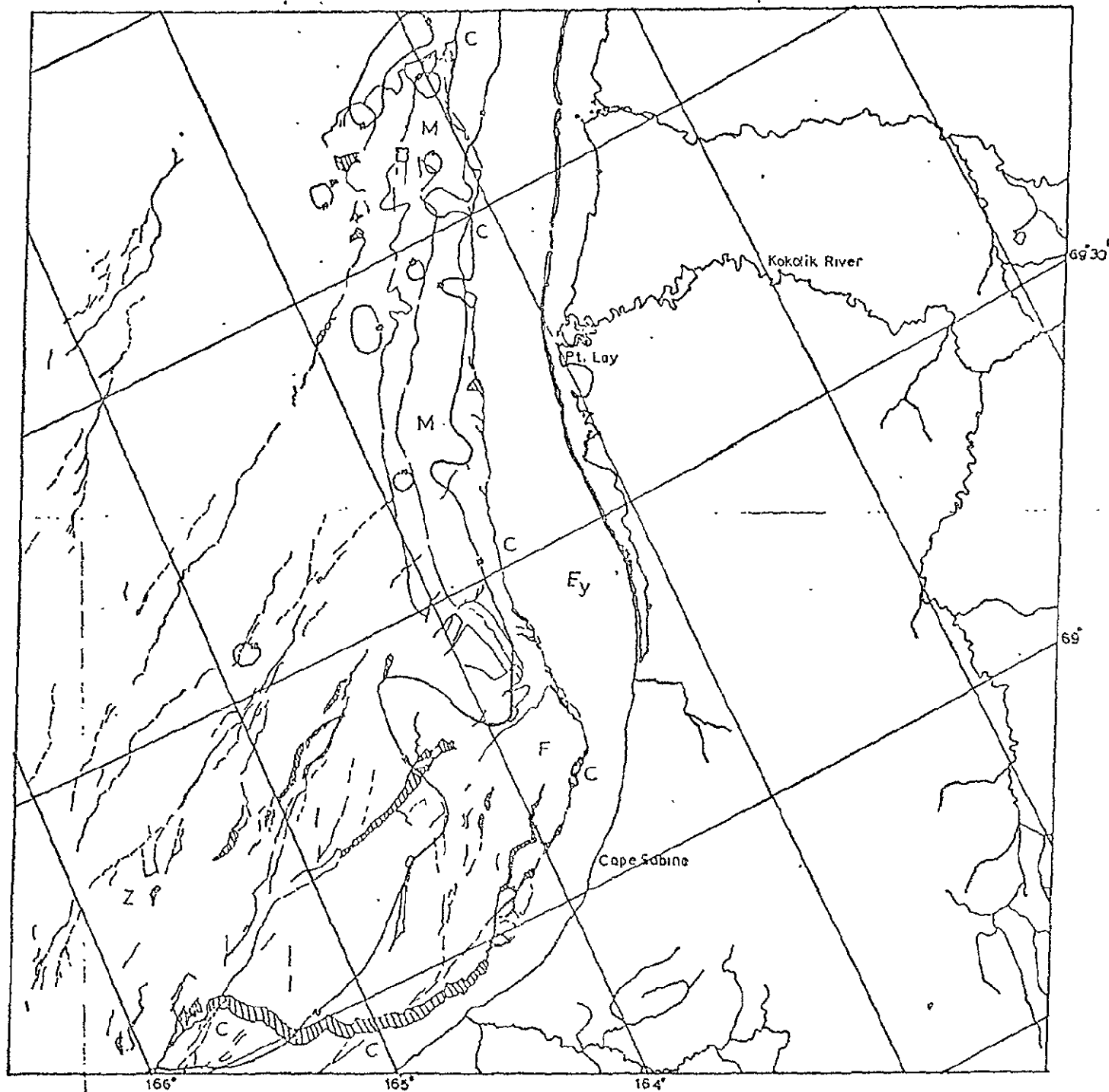
E-1981-21521-7  
31 MARCH 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE: APPROX 1:1,000,000

CHUKCHI SEA

E-1982-21562-7  
1 APRIL 1975

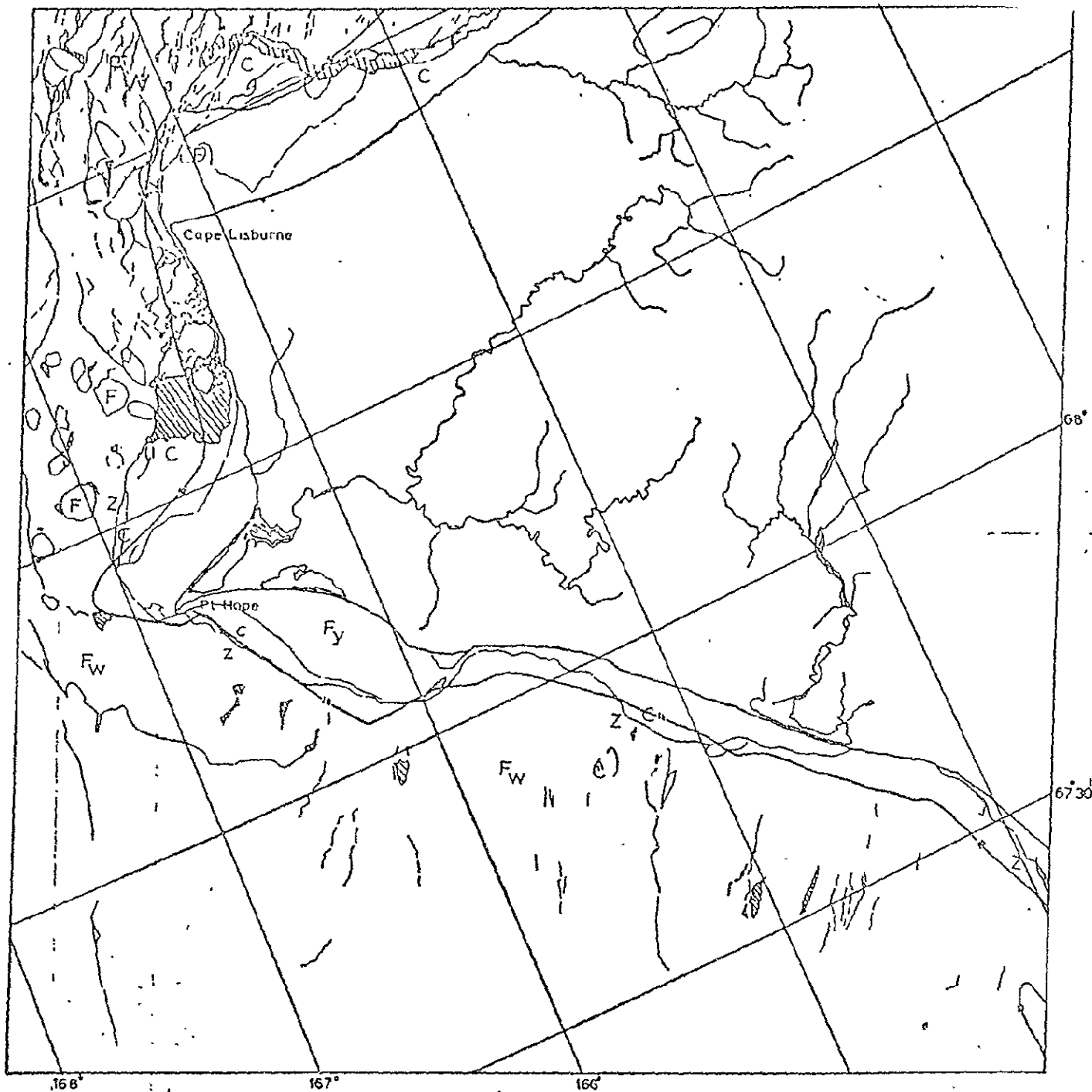


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1982-21564-7  
 1 APRIL 1975

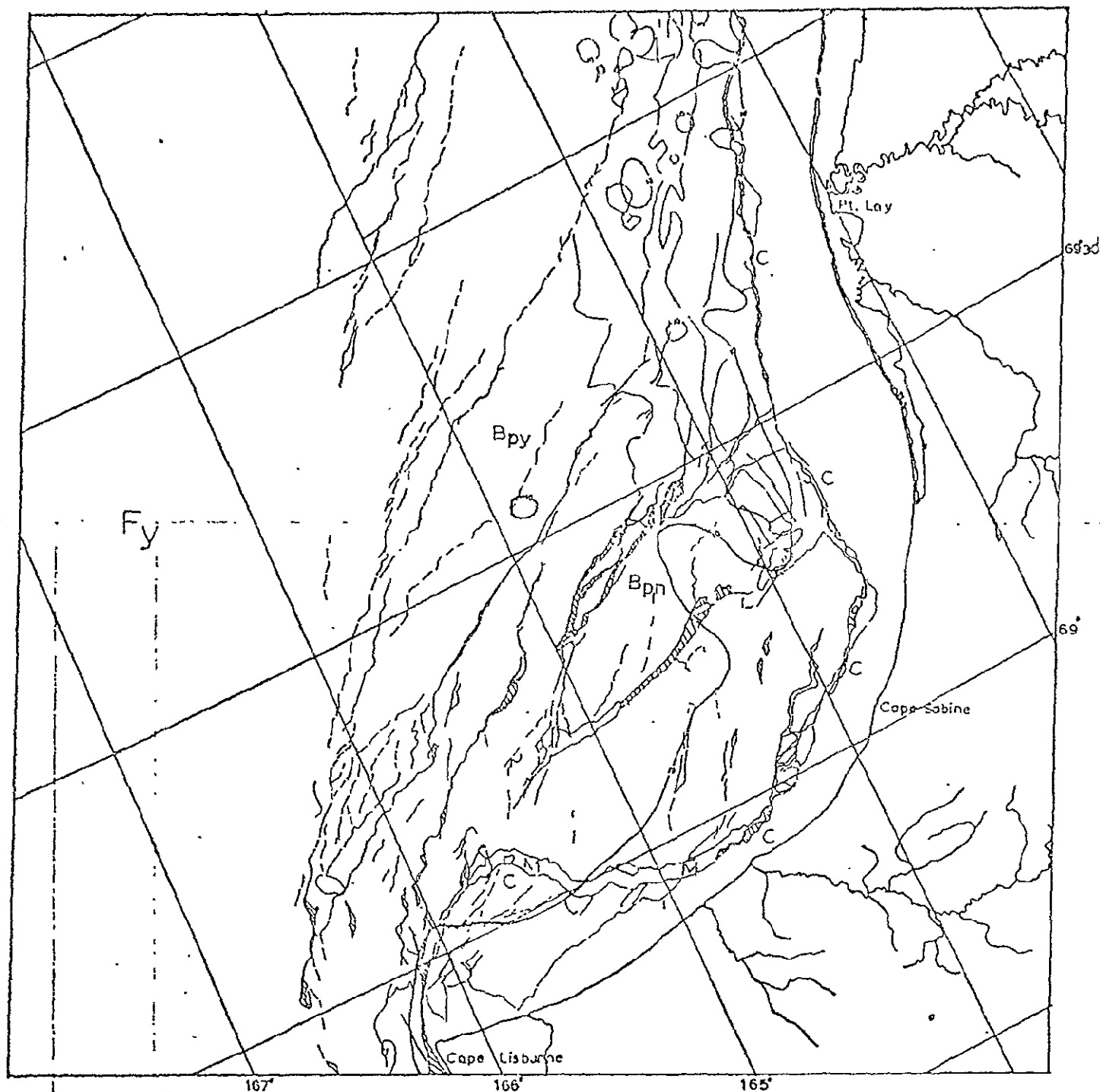




KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

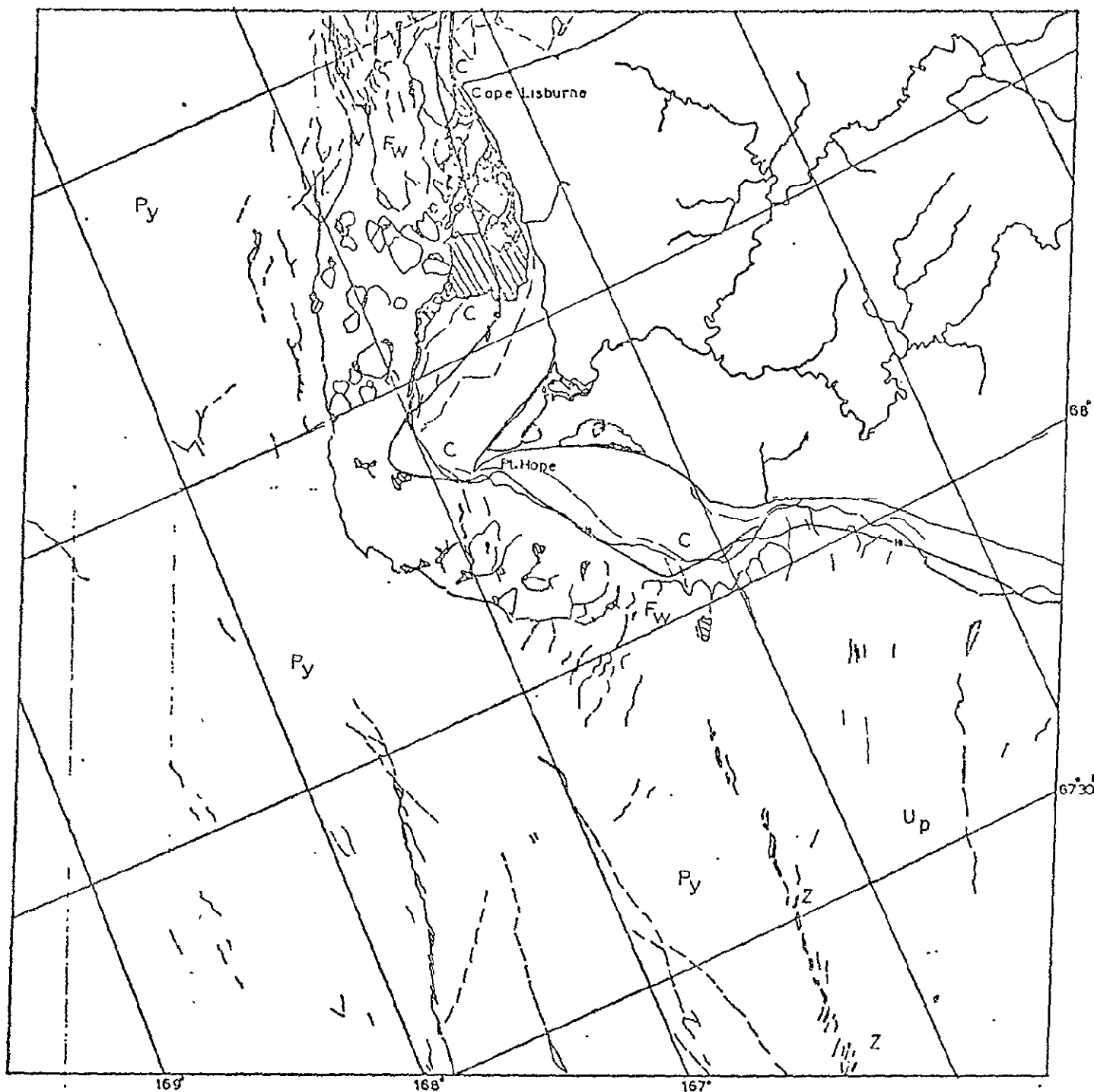
E-1982-21571-7  
1 APRIL 1975



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

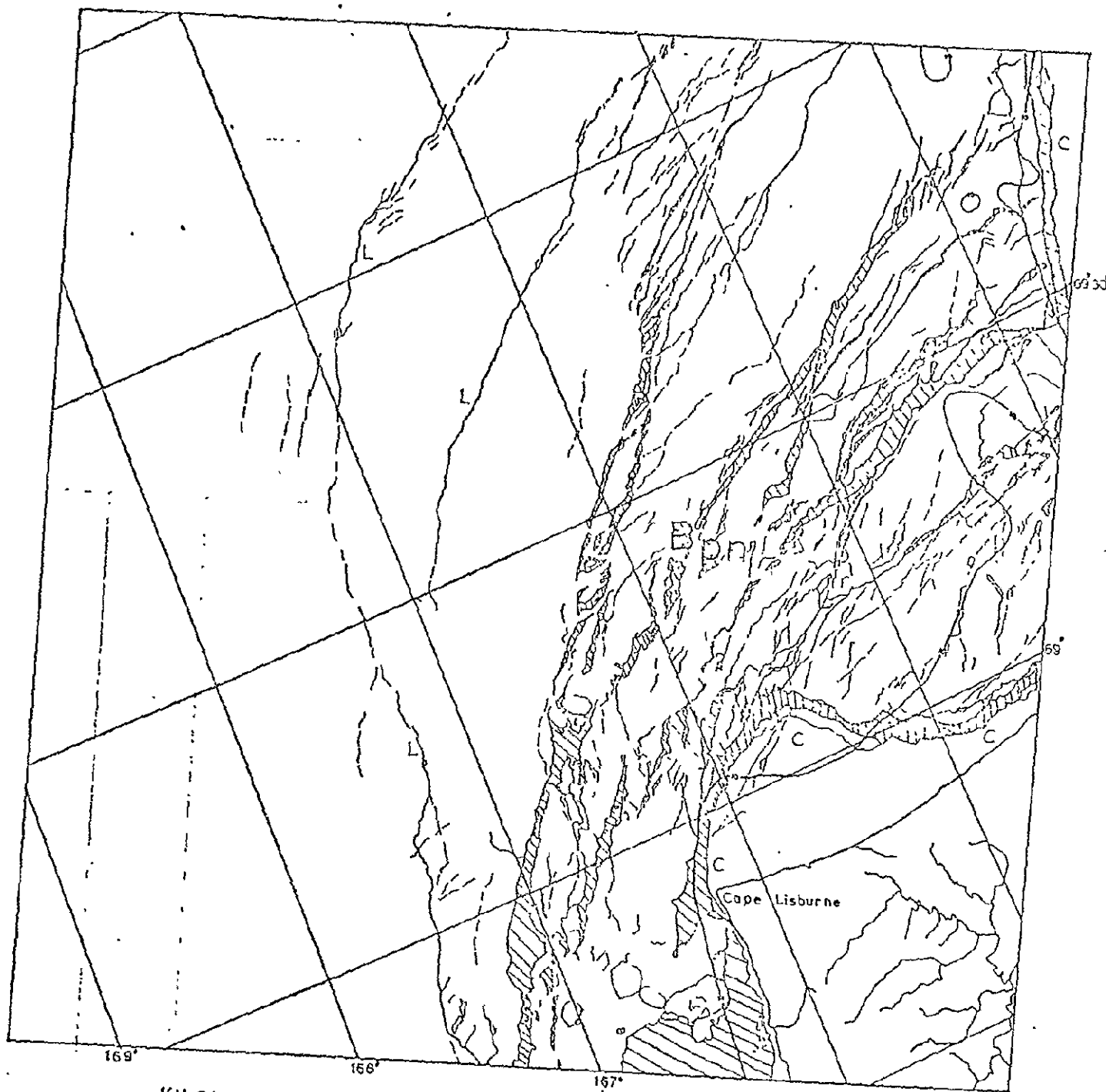
E-1983-22022-7  
 2 APRIL 1975



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

E-1983-22025-7  
 2 APRIL 1975

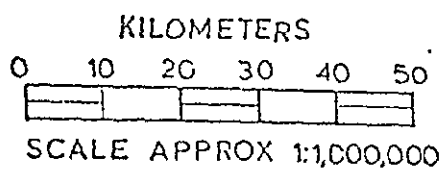
CHUKCHI SEA



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-1984-22080-7  
3 APRIL 1975



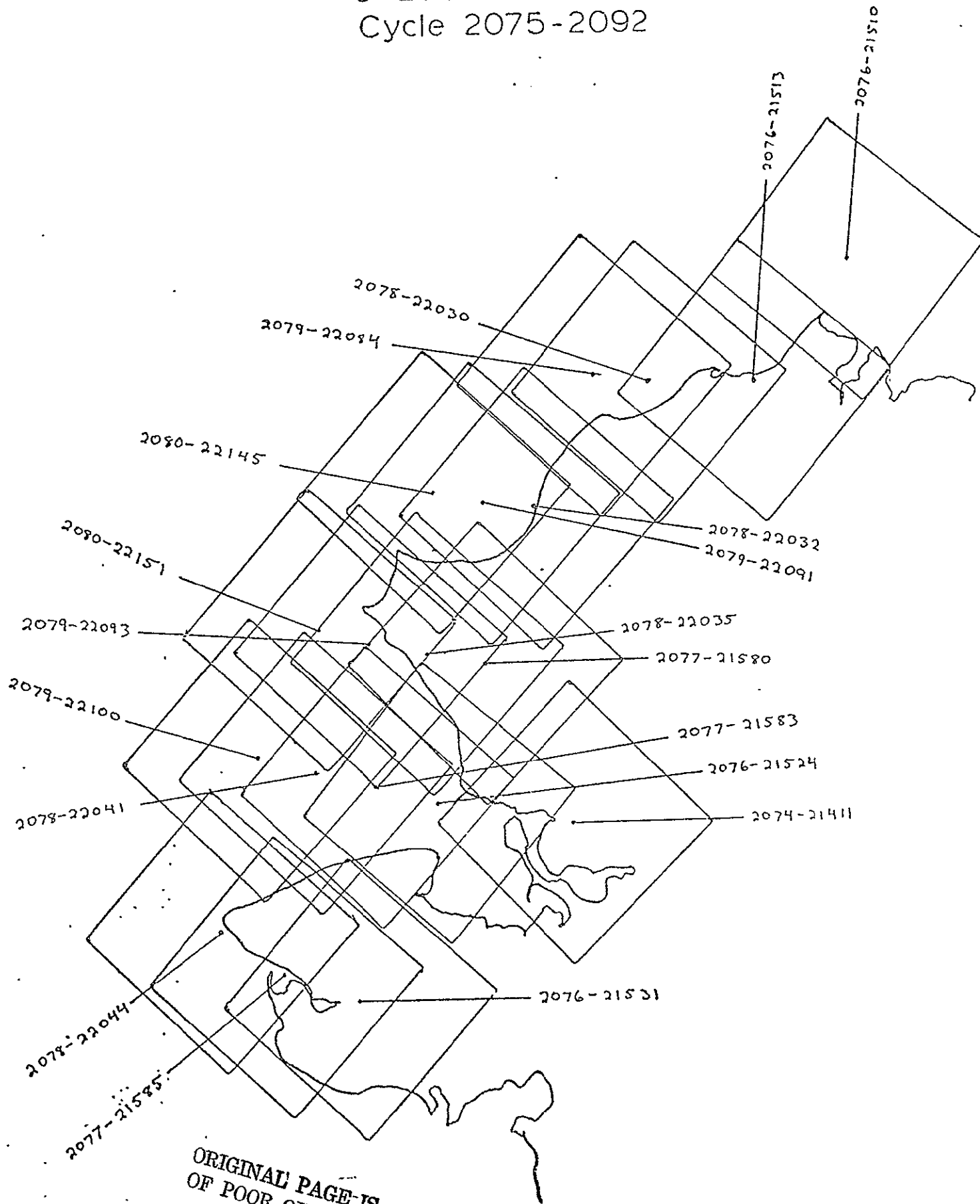
3 APRIL 1975

CHUKCHI SEA

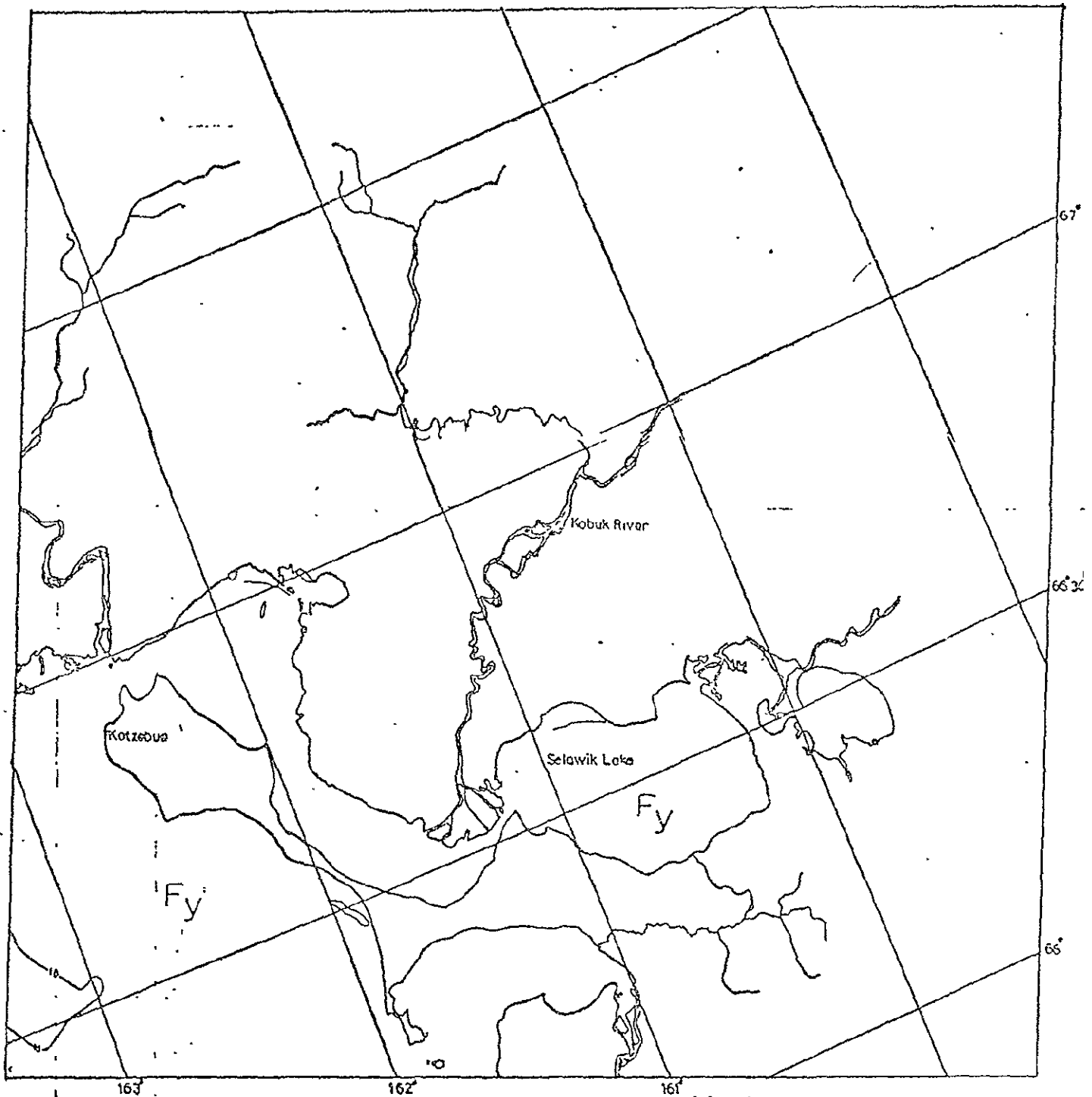
# CHUKCHI SEA

6-23 APRIL 1975

Cycle 2075-2092



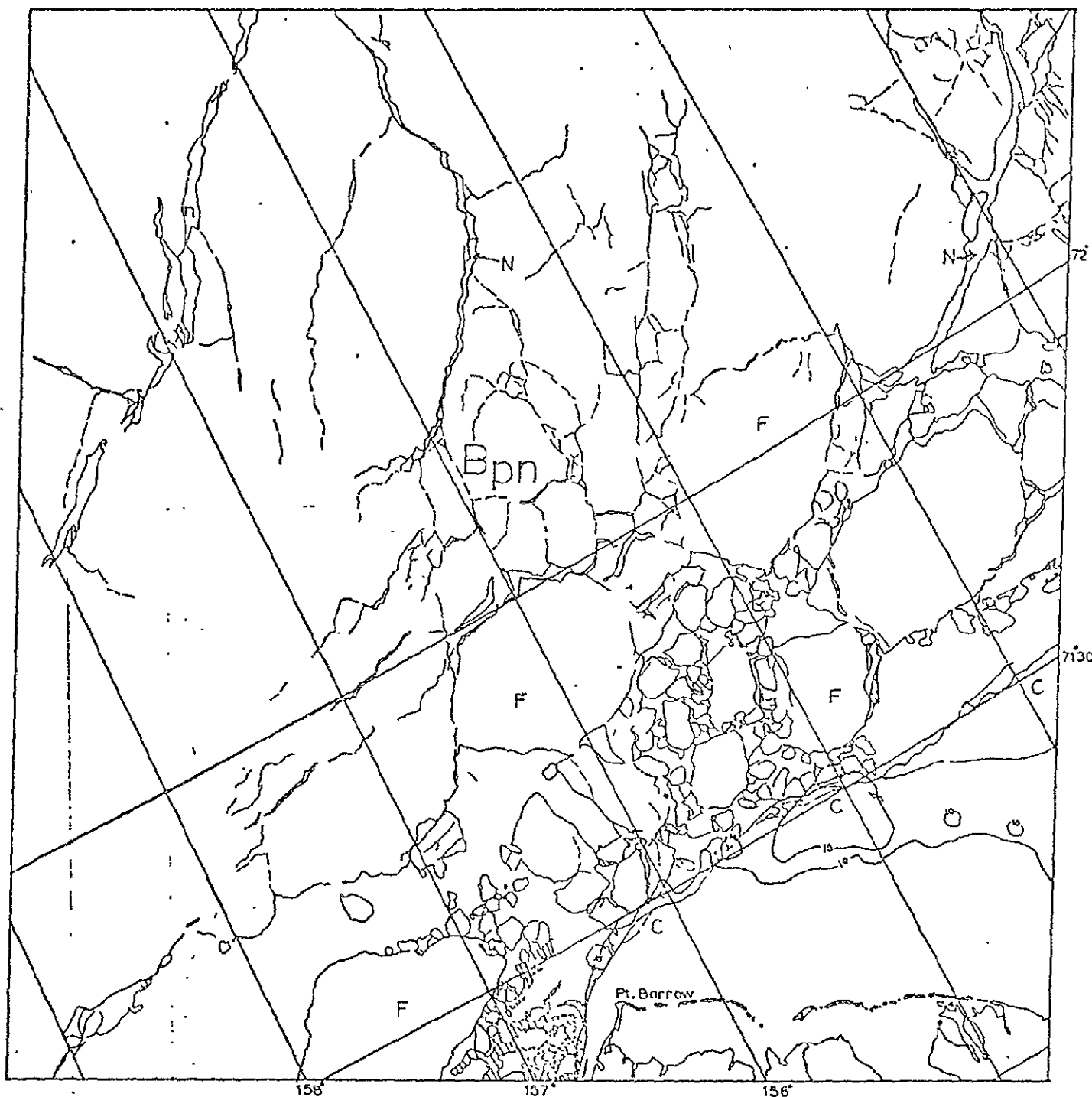
ORIGINAL PAGE IS  
OF POOR QUALITY



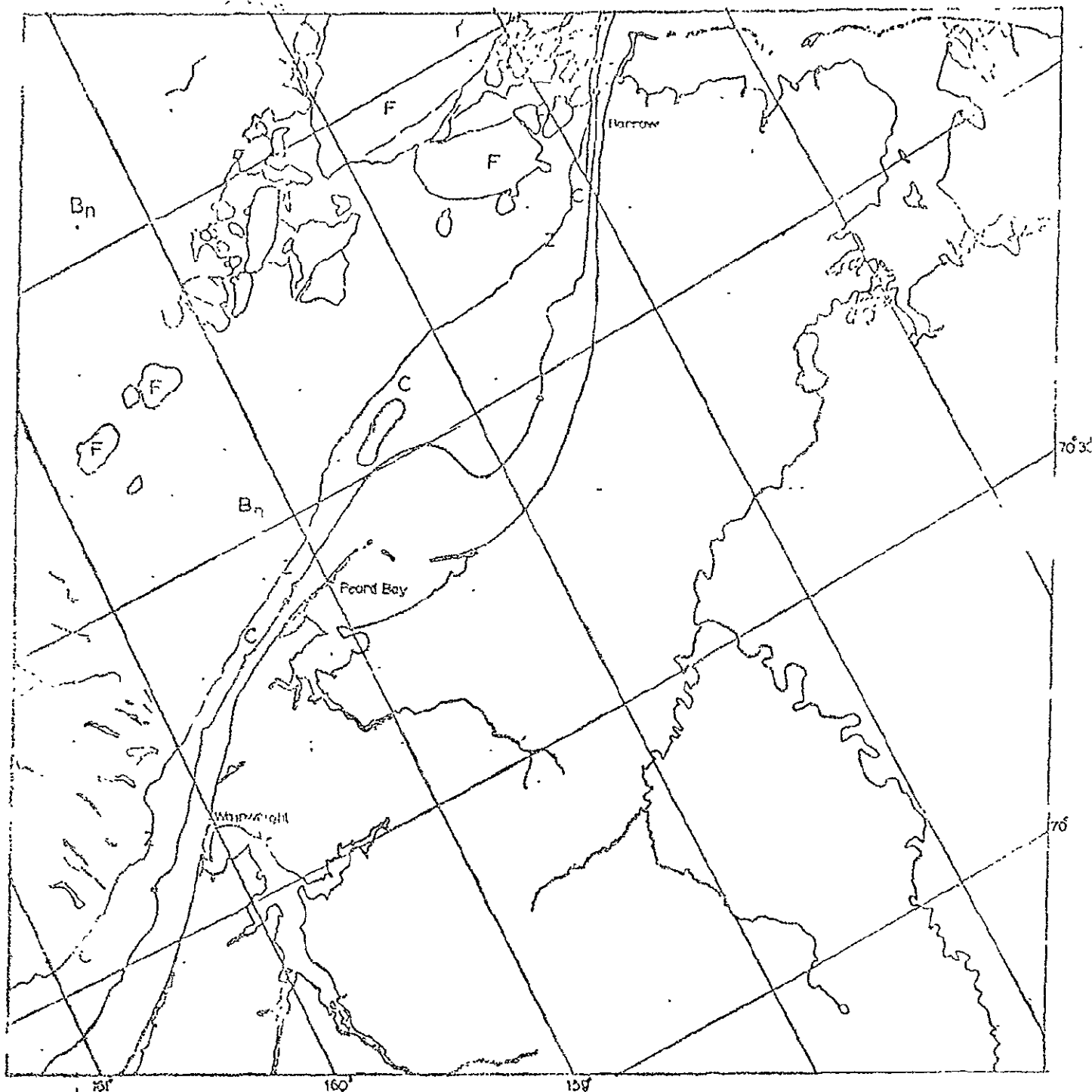
KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

E-2074-21411-7  
6 APRIL 1975

CHUKCHI SEA



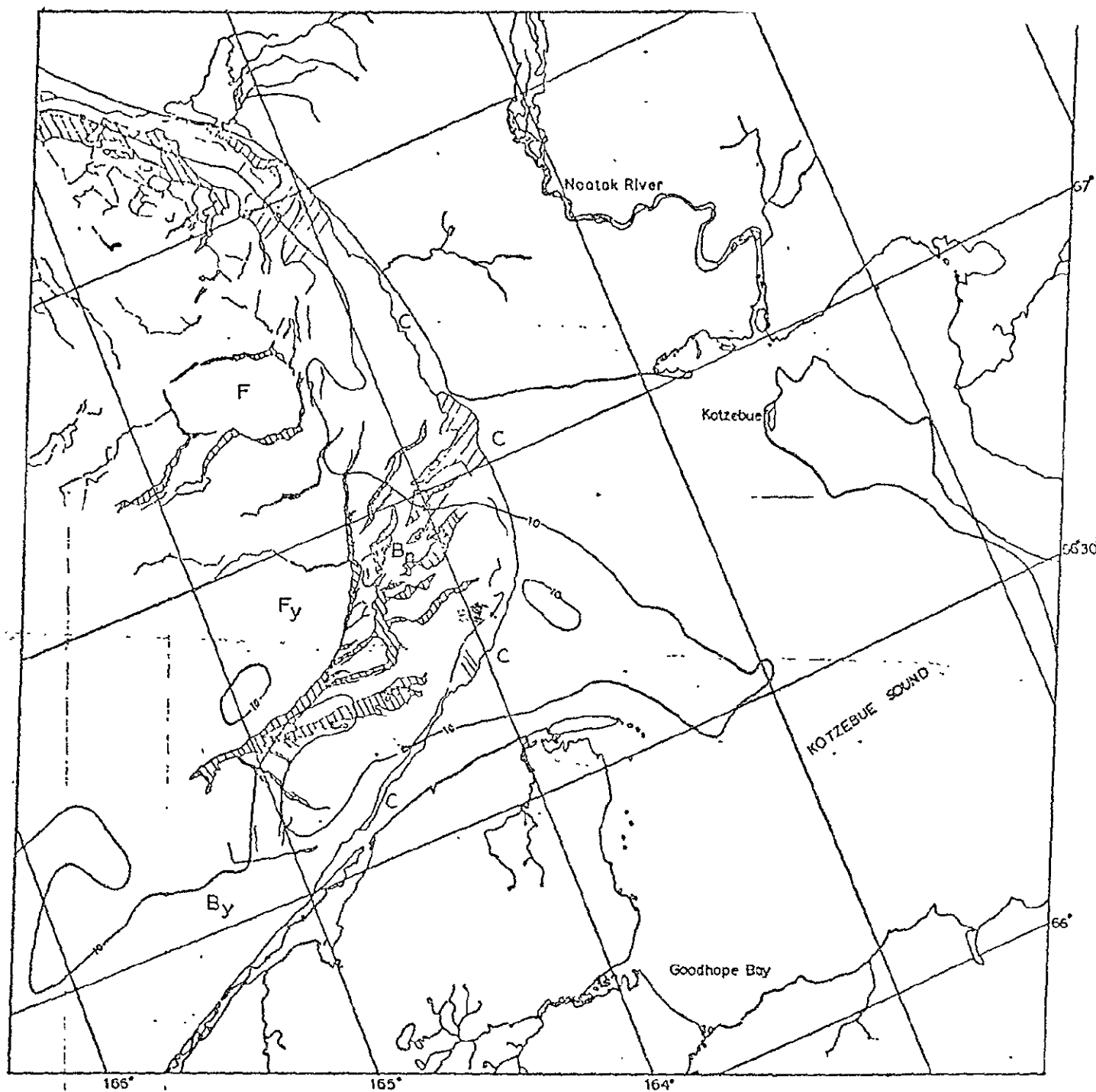




KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

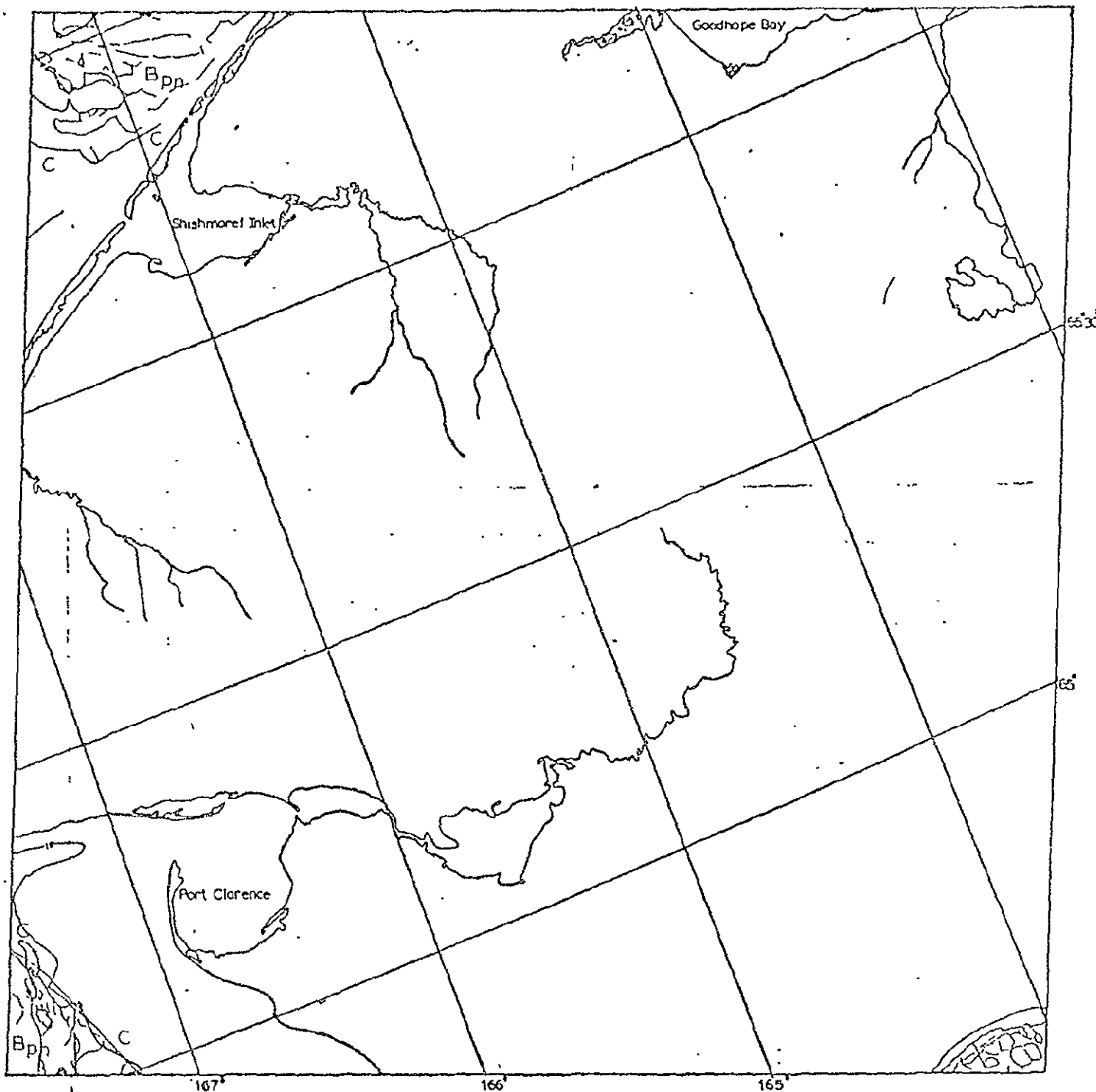
E-2076-21513-7  
 8 APRIL 1975



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

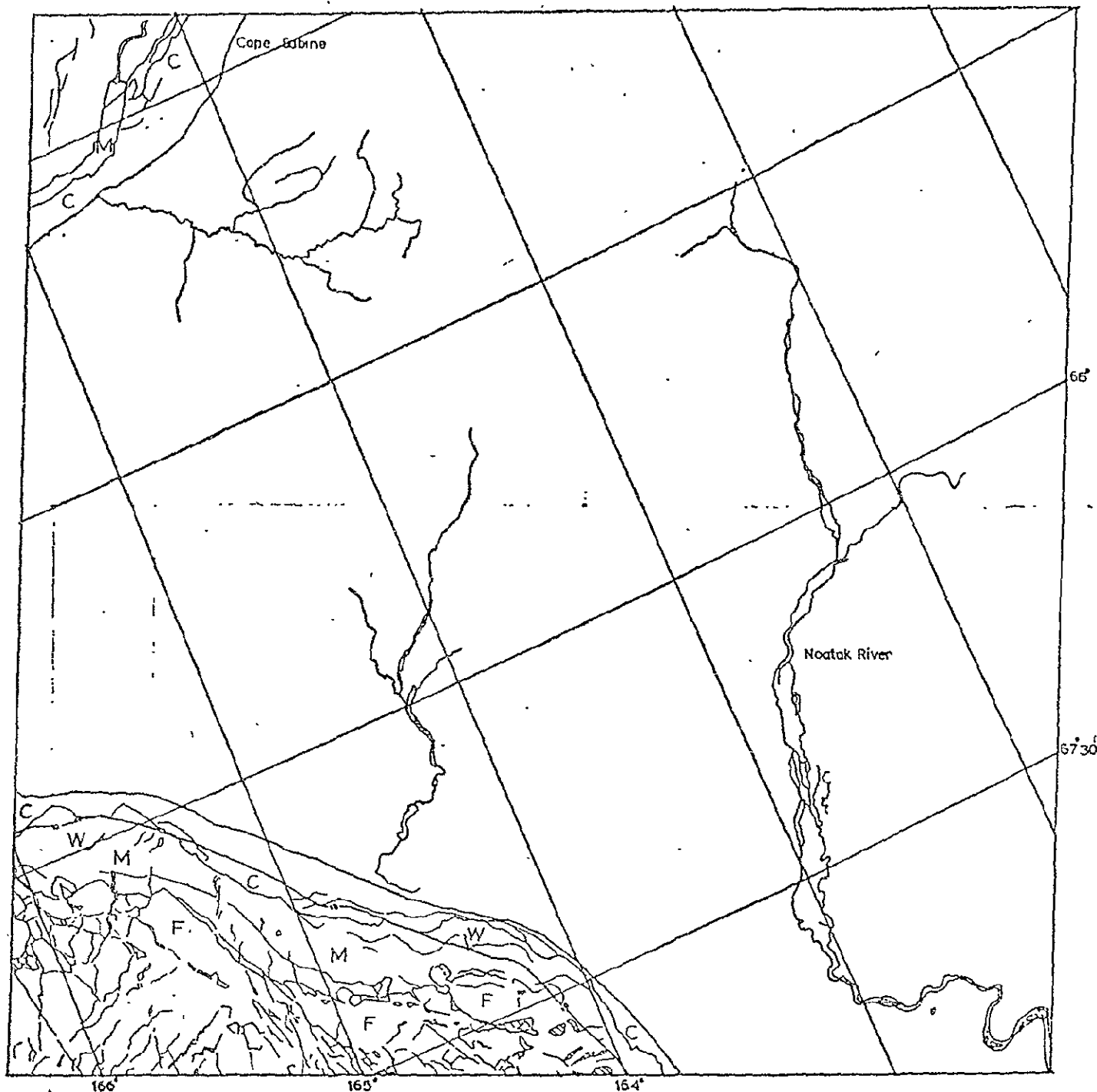
E-2076-21524-7  
 8 APRIL 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

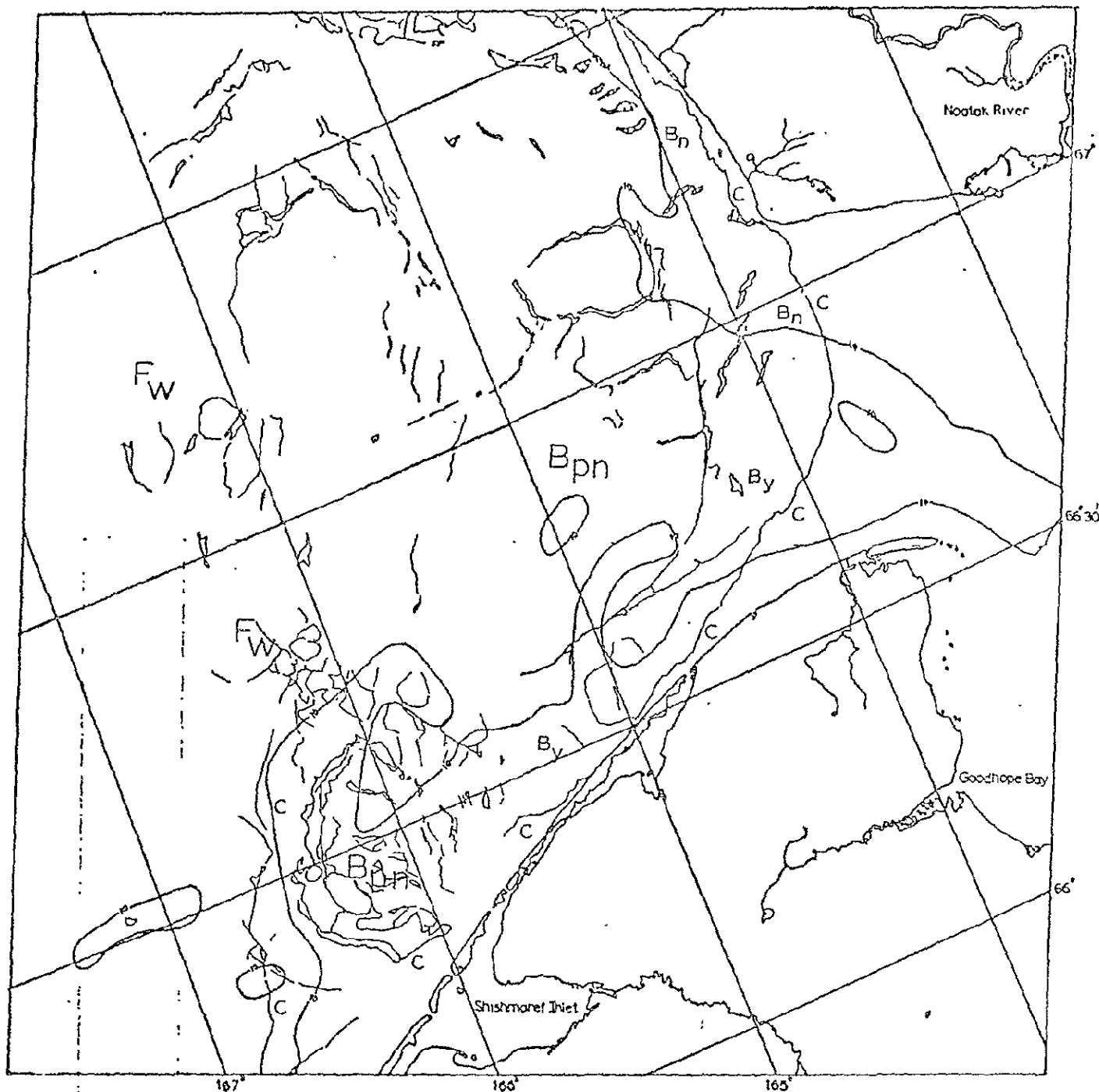
E-2076-21531-7  
8 APRIL 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

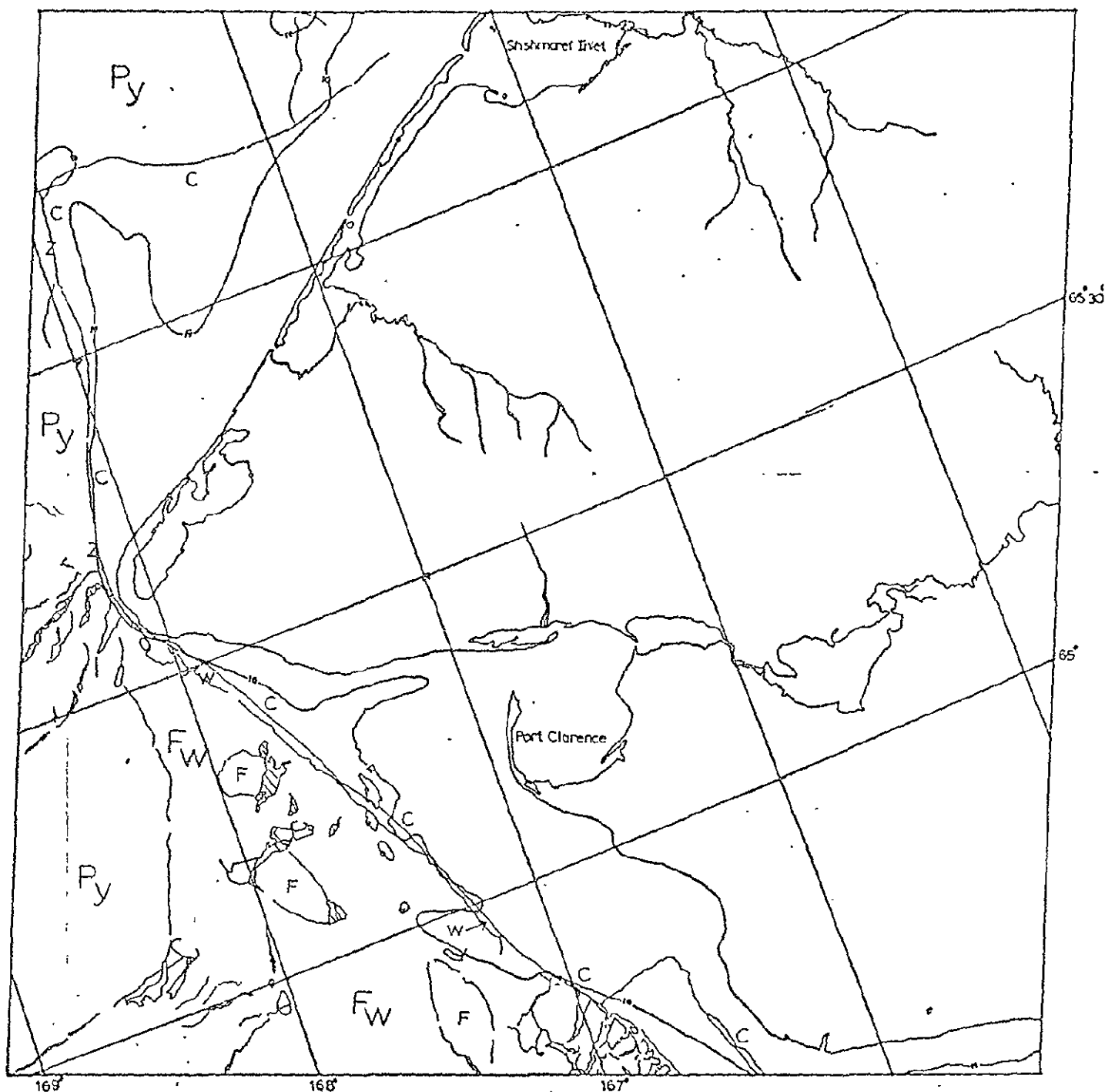
E-2077-21580-7  
9 APRIL 1975



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2077-21583-7  
 9 APRIL 1975

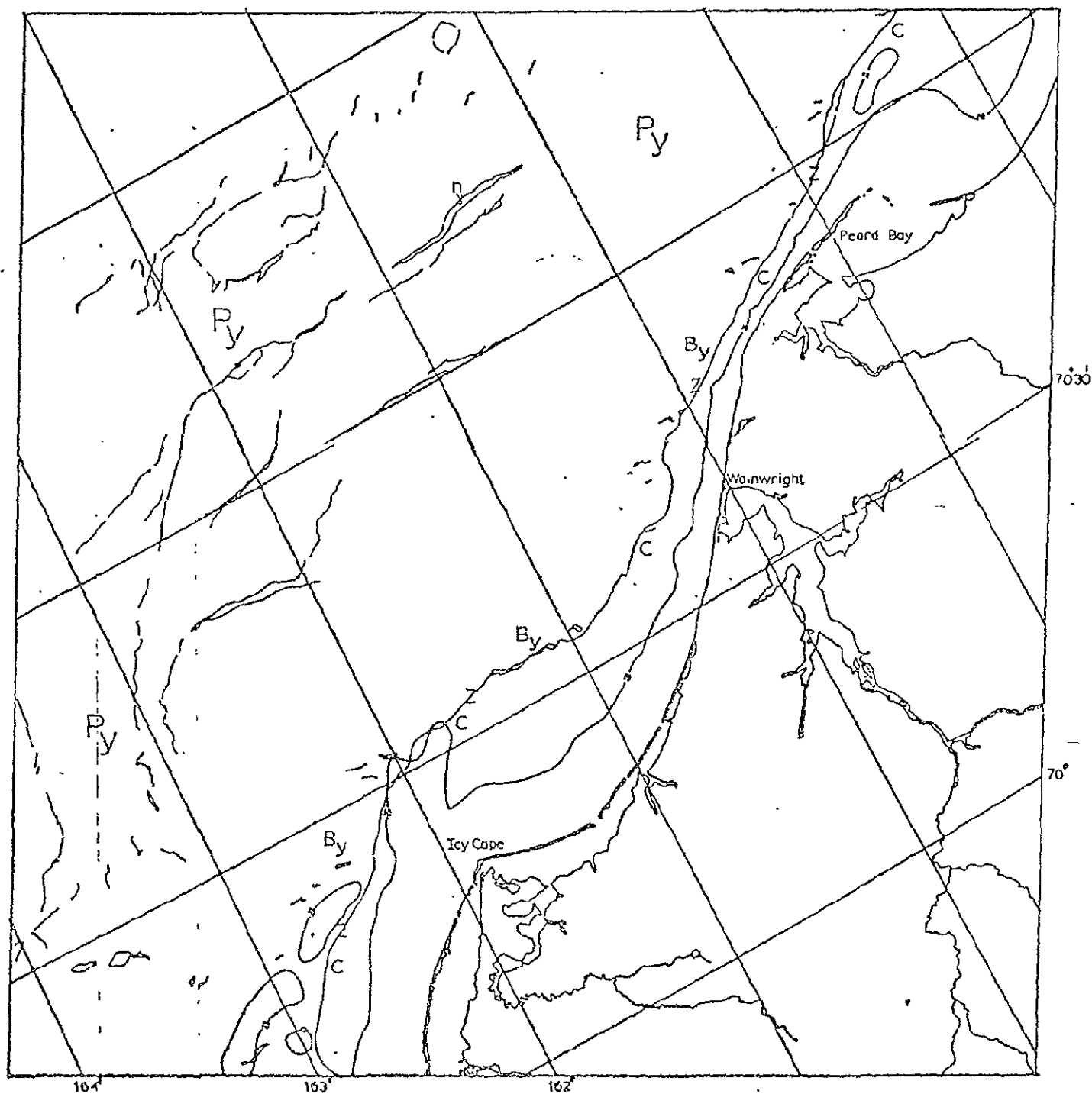


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

E-2077-21565-7  
 9 APRIL 1975

CHUKCHI SEA

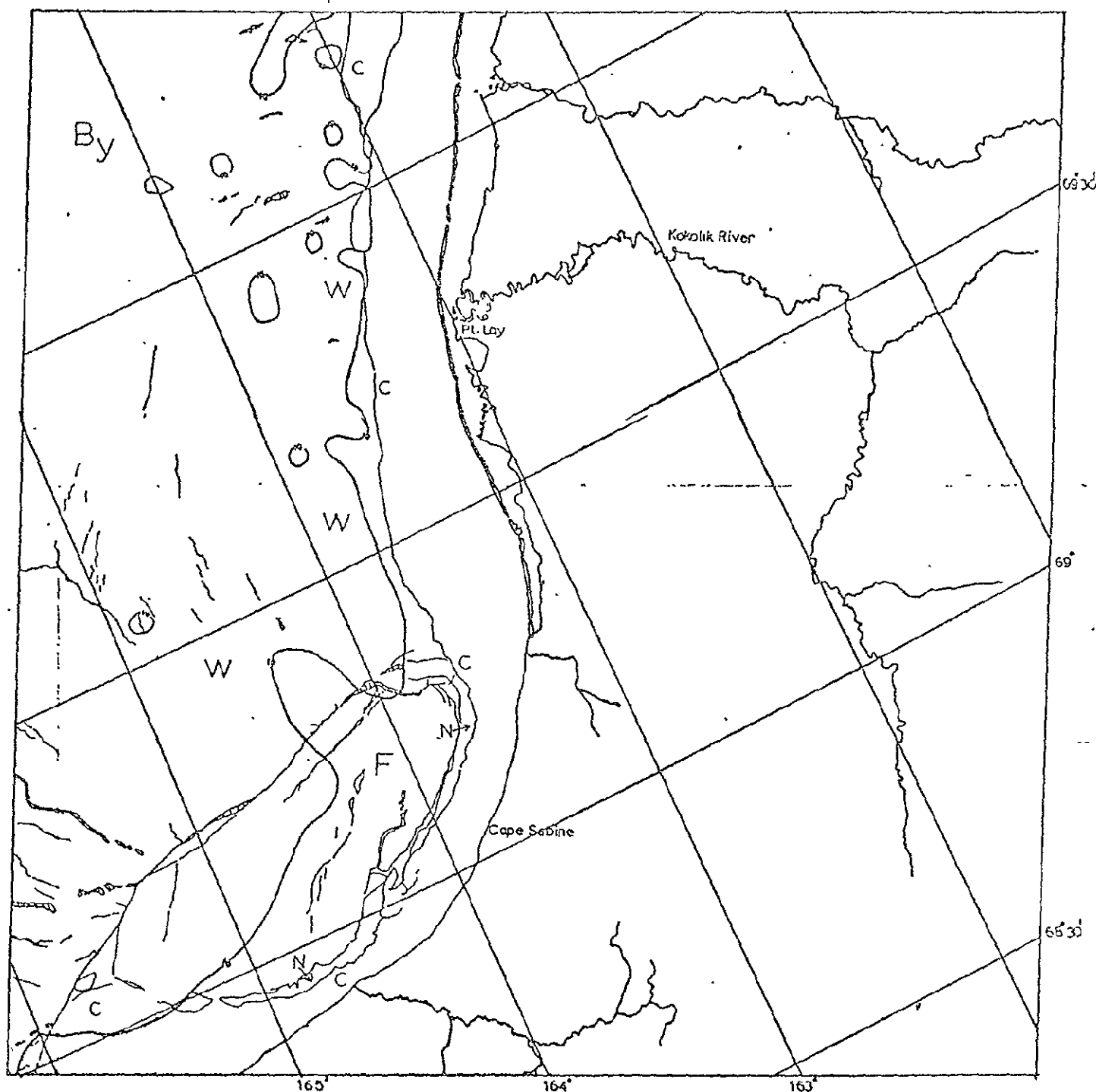
214



E-2078-22030-7  
10 APRIL 1975

CHUKCHI SEA.

215

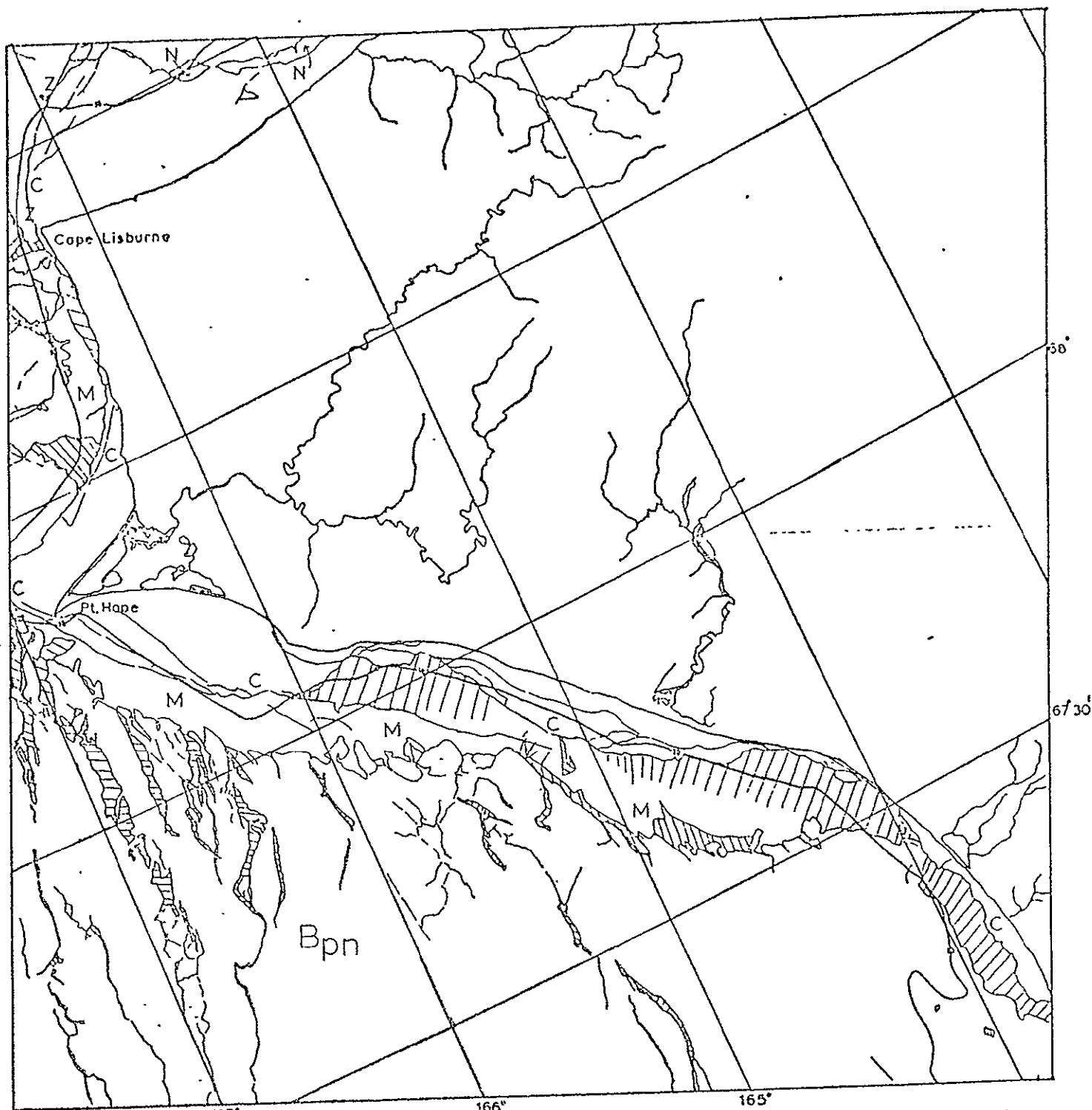


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2076-22032-7  
10 APRIL 1975

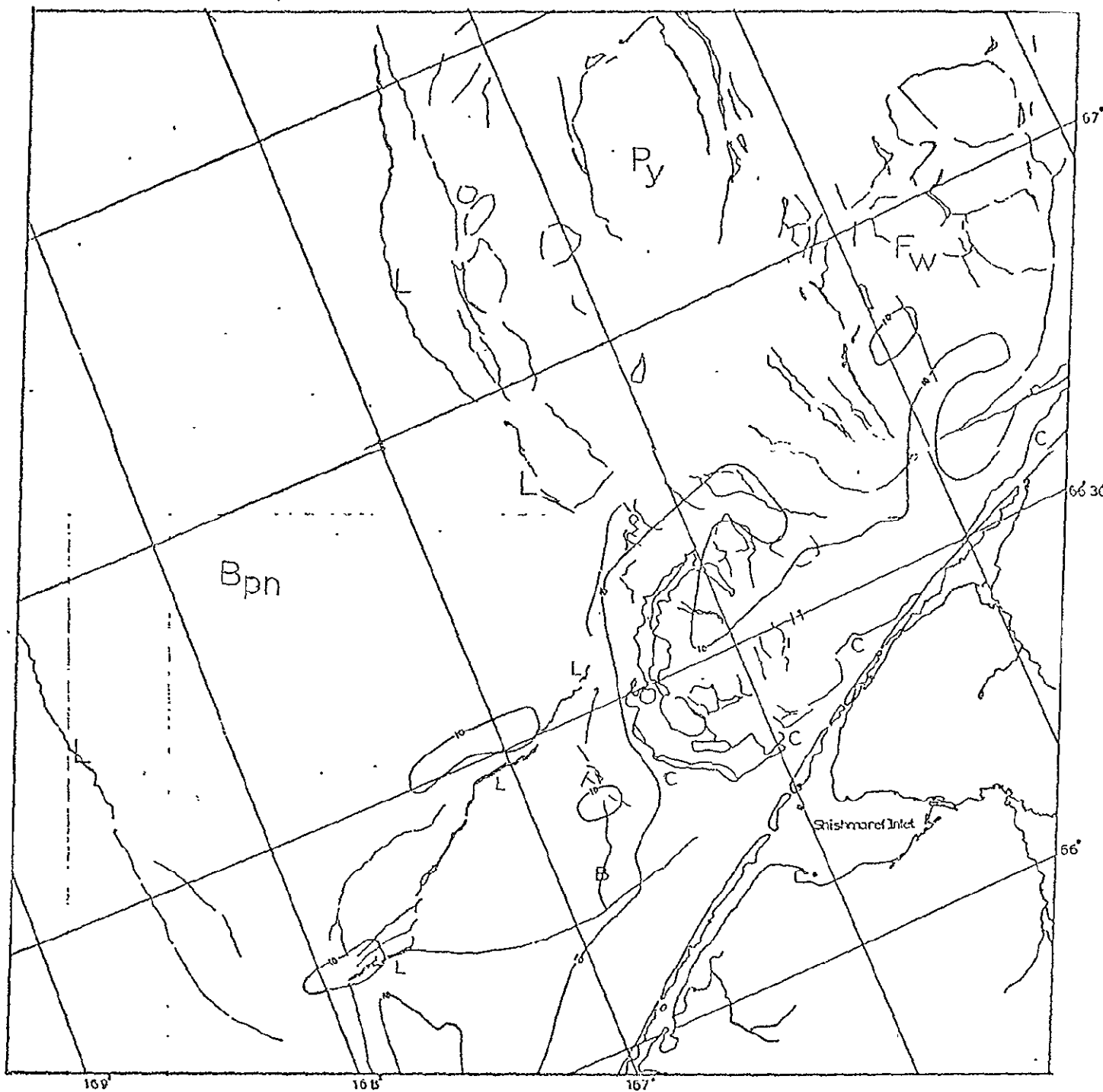




KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

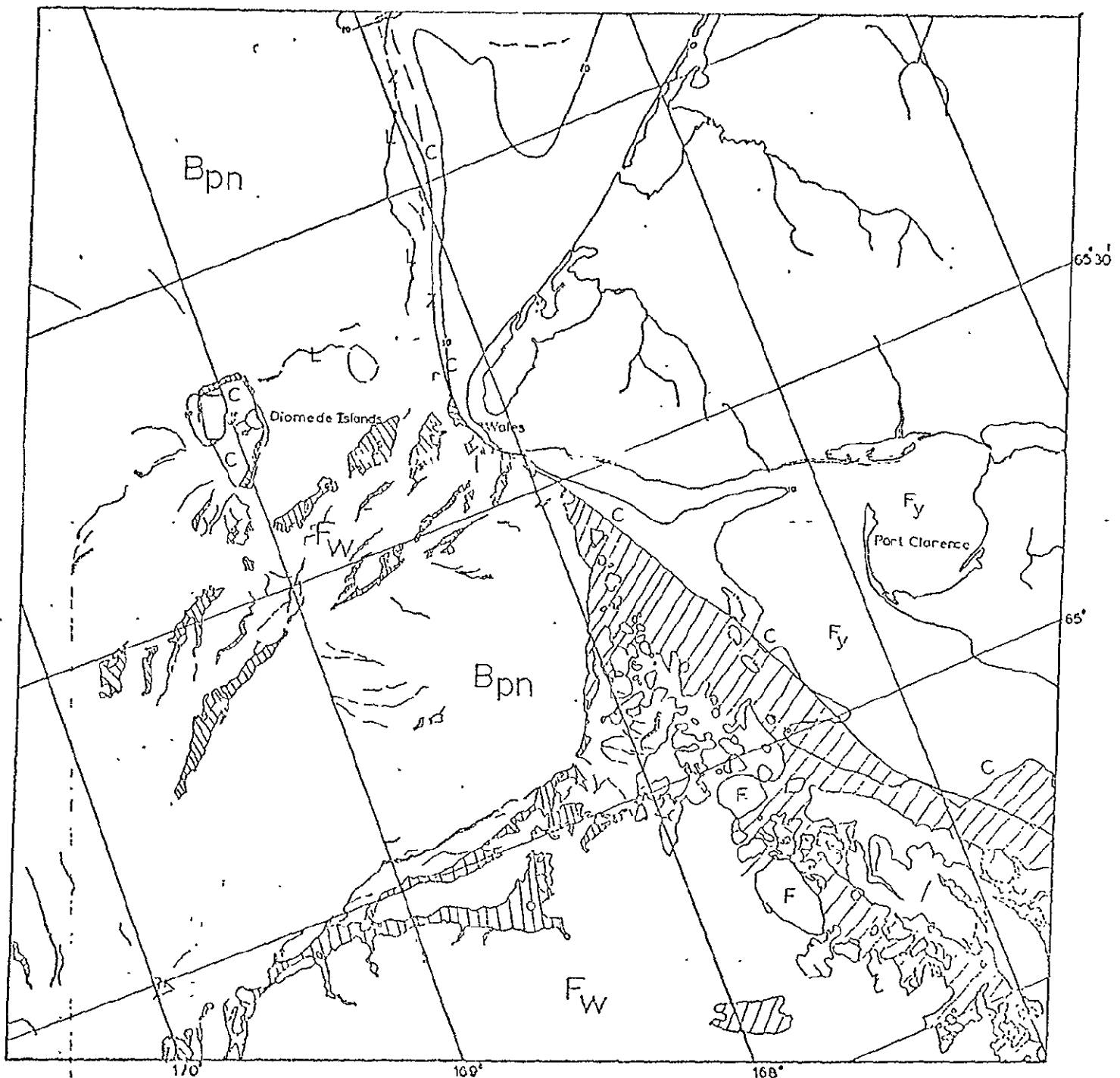
E-2078-22035-7  
 10 APRIL 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

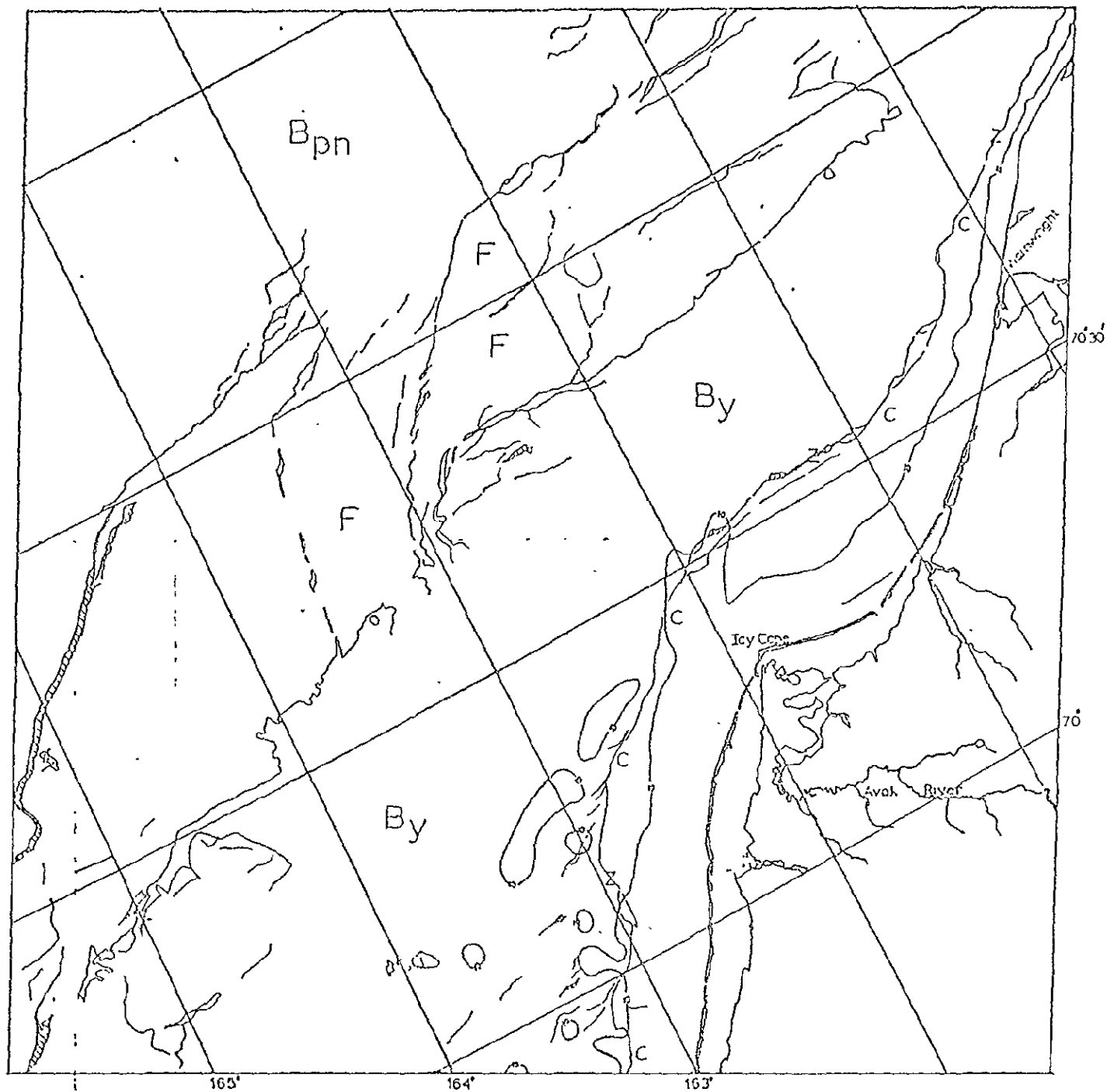
E-2070-220-11-7  
10 APRIL 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

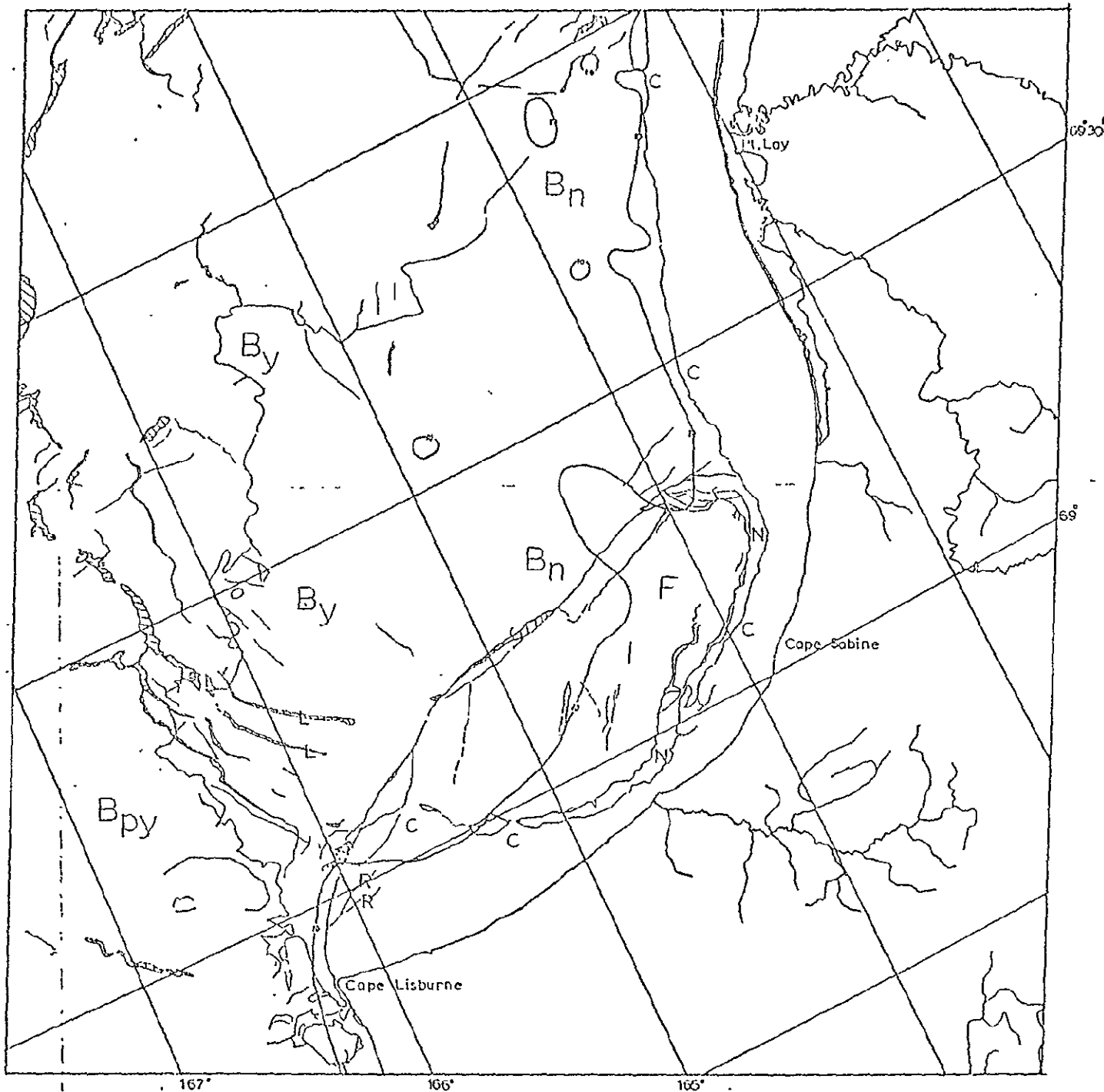
E-2078-22044-7  
10 APRIL 1975

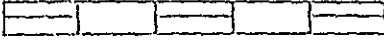


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

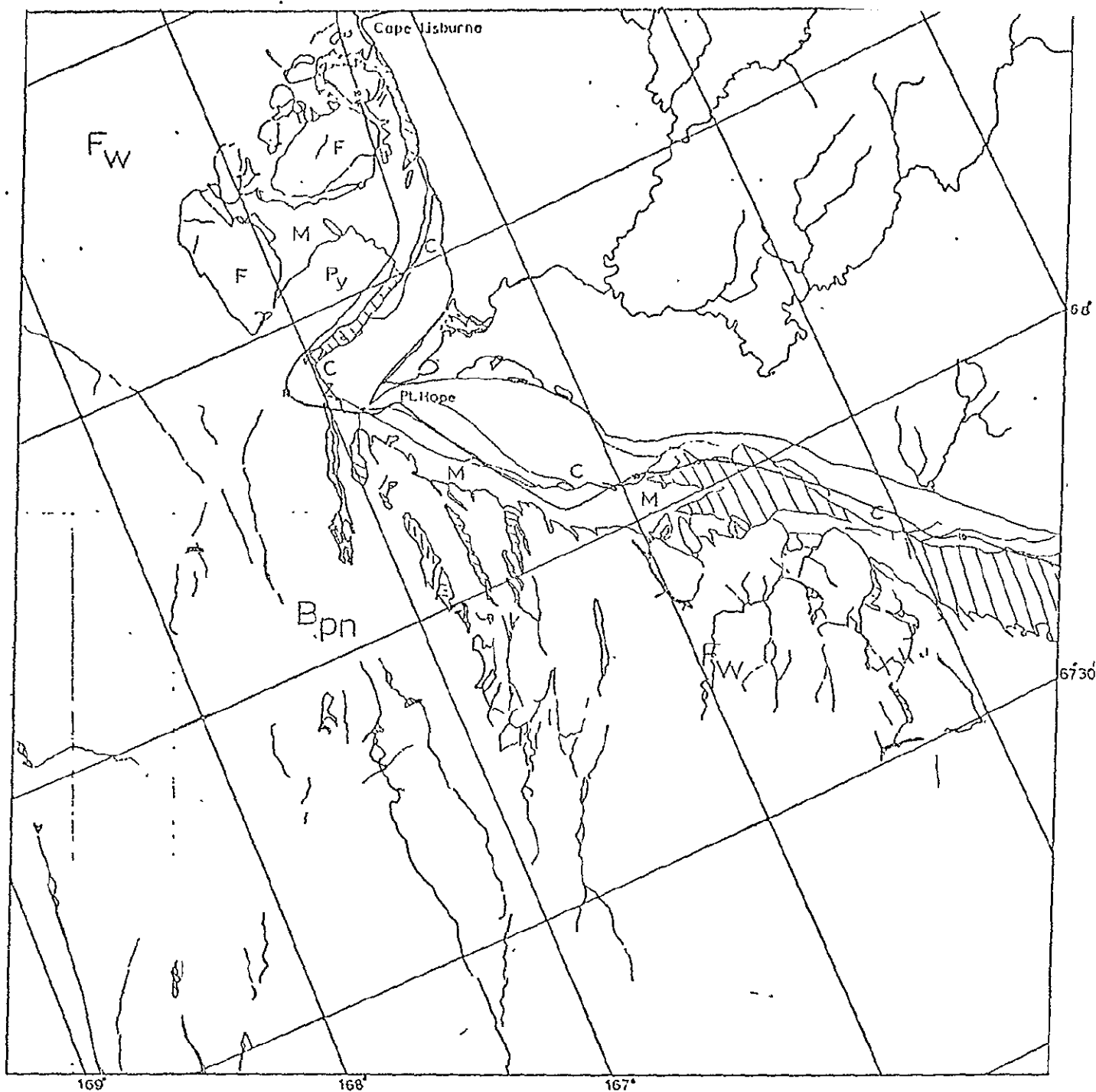
E-2079-22084-7  
 11 APRIL 1975



KILOMETERS  
 0 10 20 30 40 50  
  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

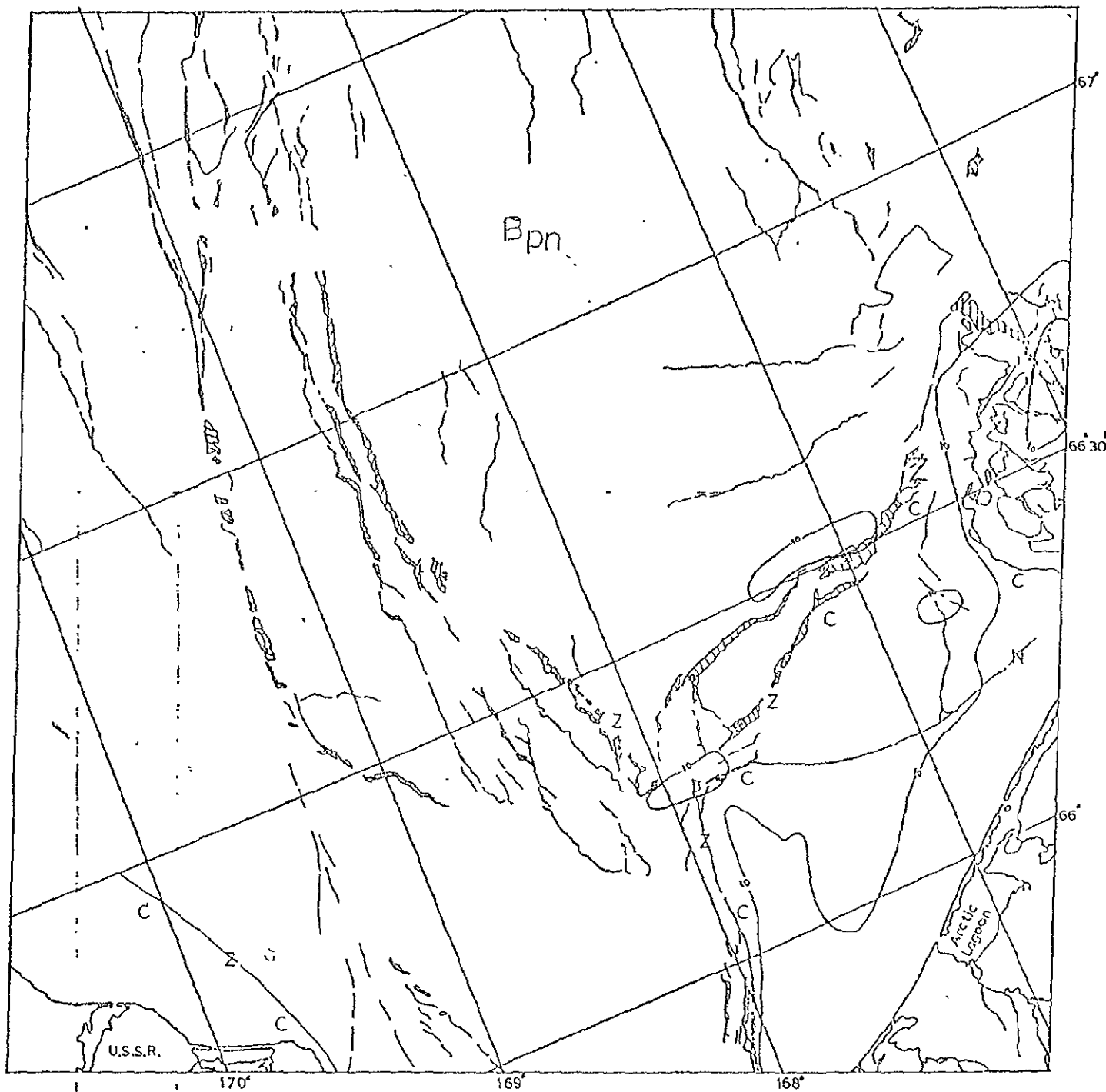
E-2079-22091-7  
 11 APRIL 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2079-22093-7  
11 APRIL 1975

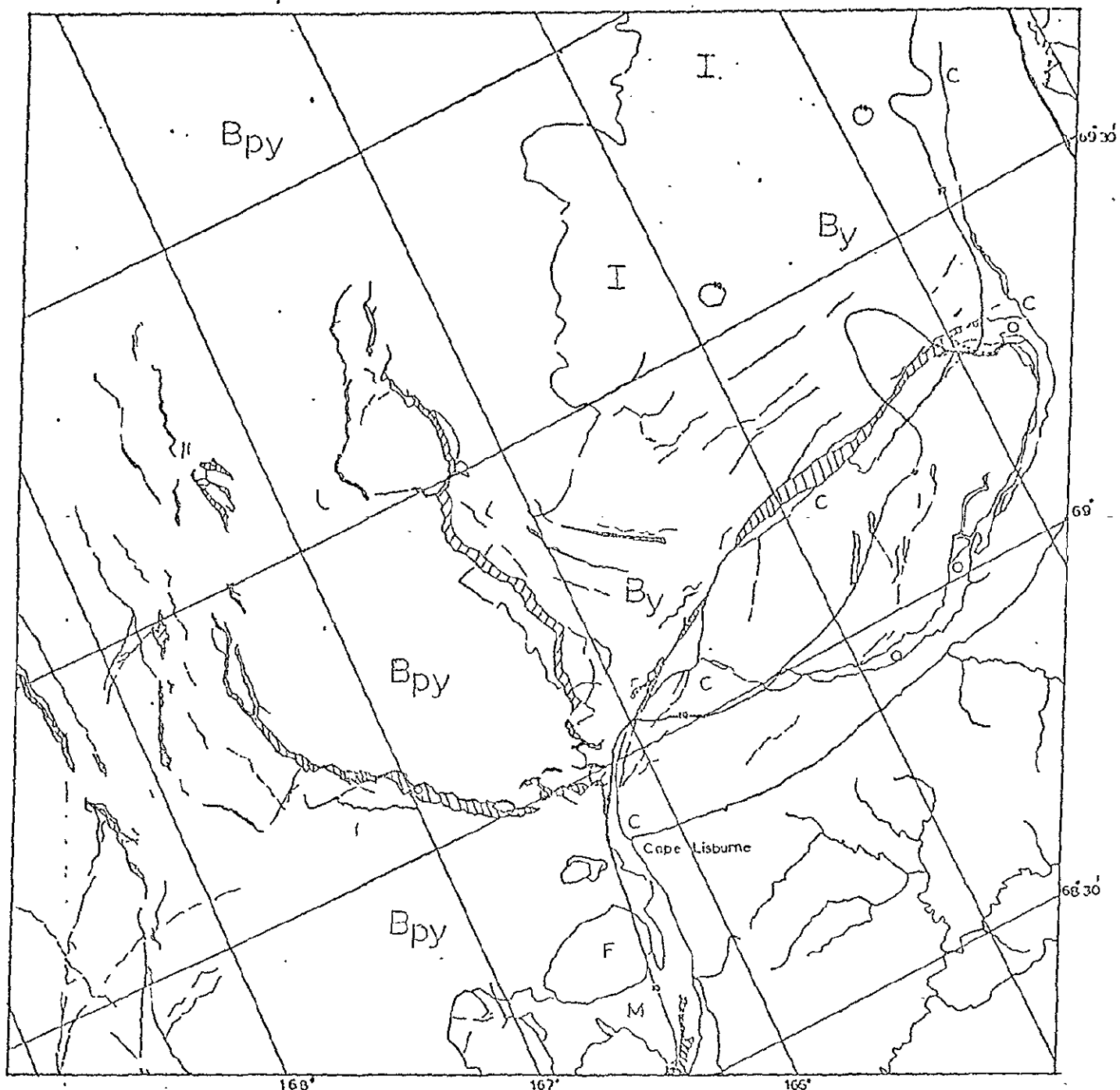


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2079-22100-7

11 APRIL 1975

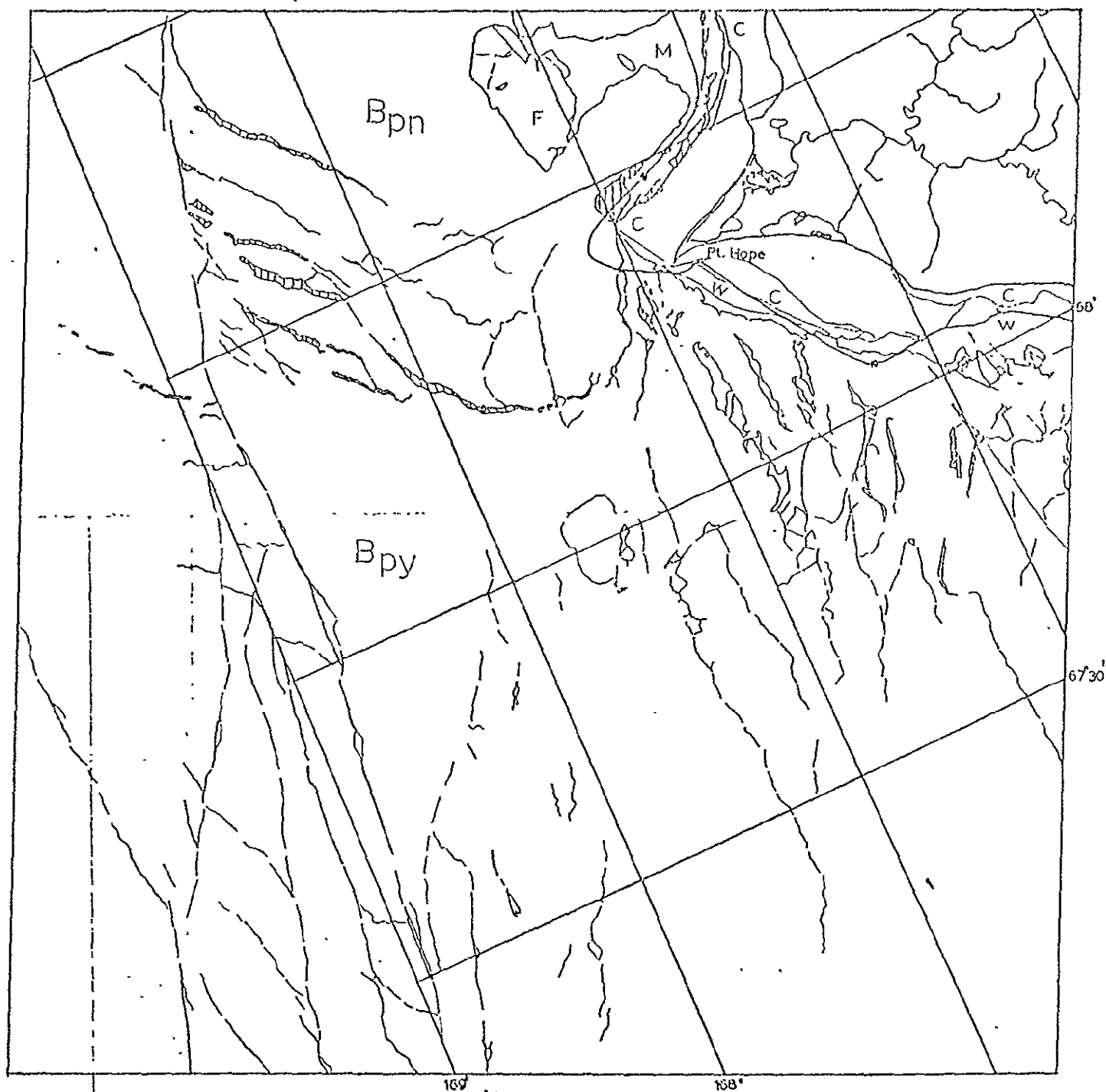


KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2080-22145-7  
 12 APRIL 1975





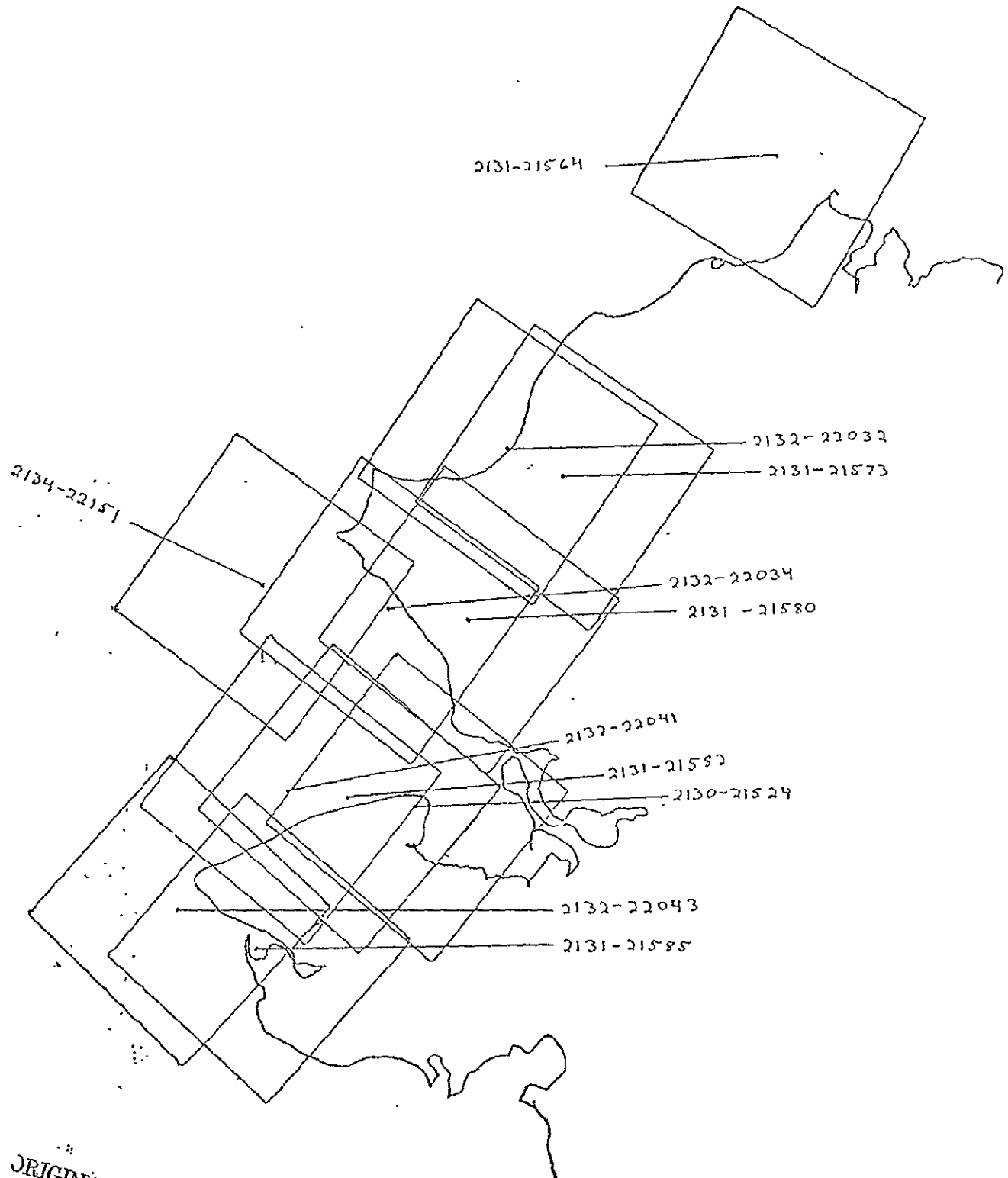
KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2030-22151-7  
 12 APRIL 1975

# CHUKCHI SEA.

30 MAY-16 JUNE 1975  
Cycle 2128-2145



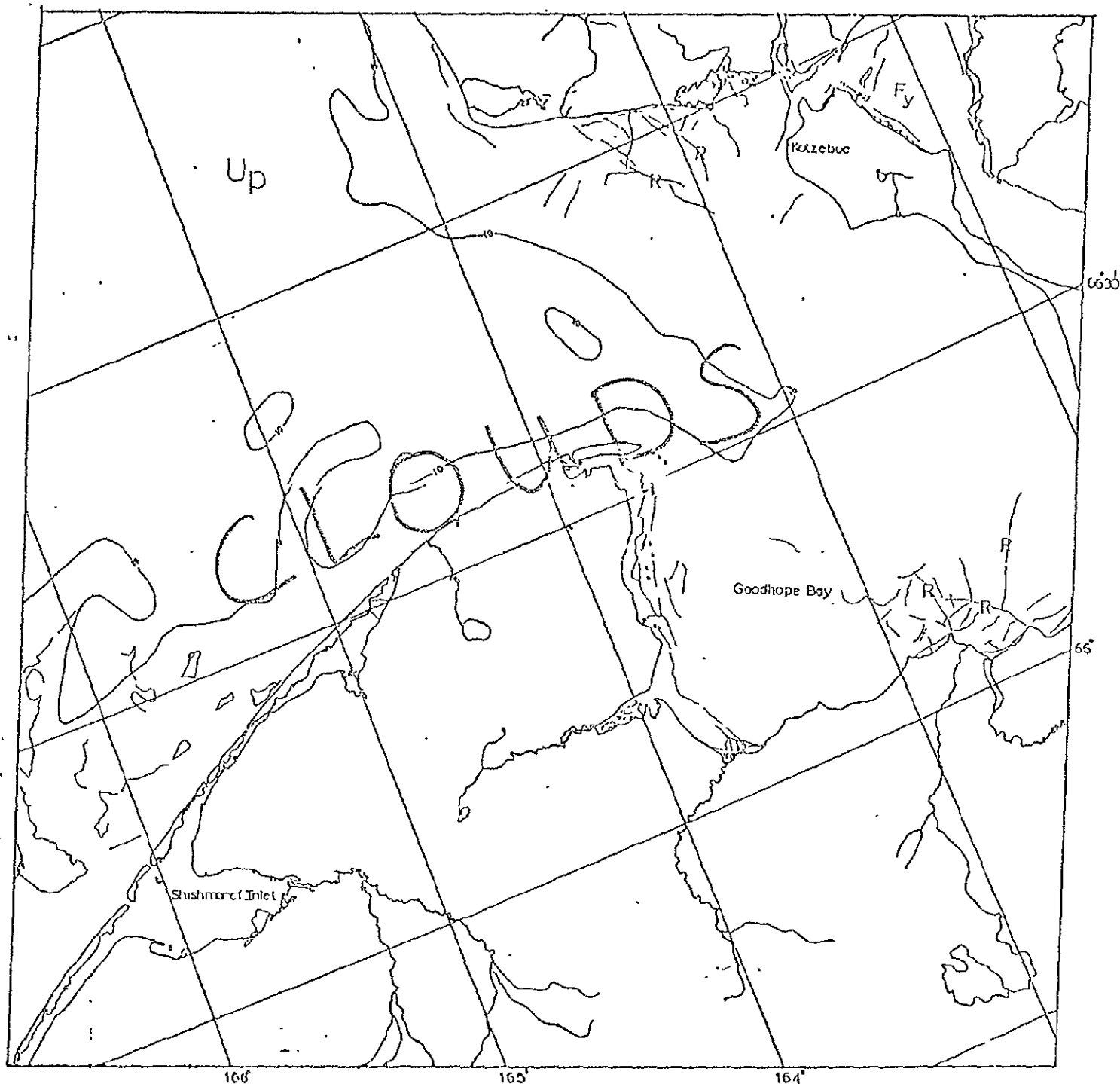
ORIGINAL PAGE IS  
OF POOR QUALITY

Scenes 2130-21524 through 2165-21454

These scenes show major portions of the Chukchi coast between June 1-6 and on July 6, 1975. The major value in this imagery is documentation of ice apparently stranded, protected by stranded ice or protected by geographic features and remaining in place at this late time.

North of Cape Prince of Wales, ice remains over the large expanse of shoals in that area. Near shore ridges remain off Cape Krusenstern. Along the coast between there and Point Hope areas of ice remains in various protected locations. At Point Hope and Cape Lisburne ice remains--apparently stranded on shoals to the north. Just north of Cape Lisburne the contiguous apron indents toward the shore well inside the 10-fathom contour, and then broadens again.

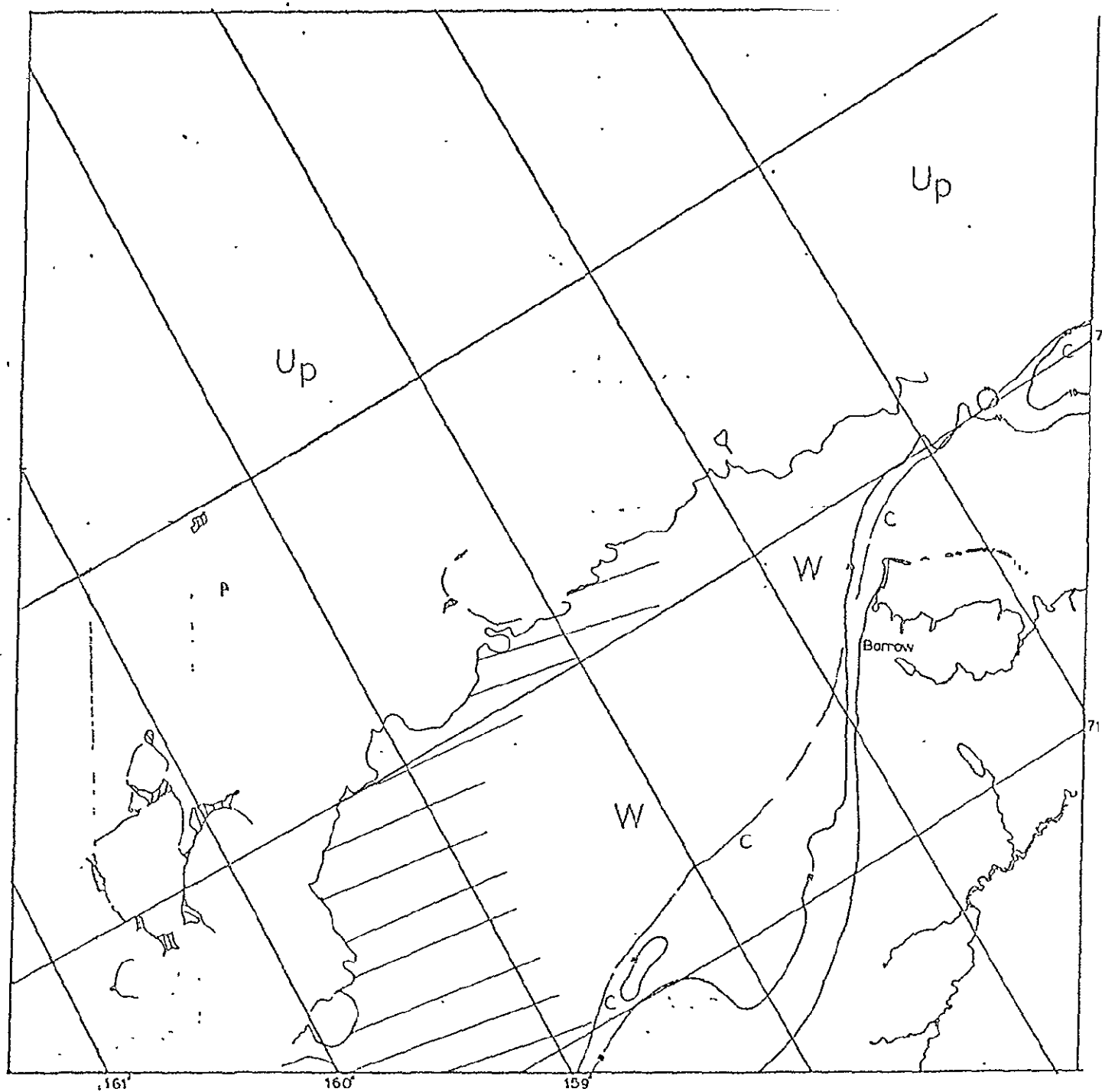
ORIGINAL PAGE IS  
OF POOR QUALITY



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

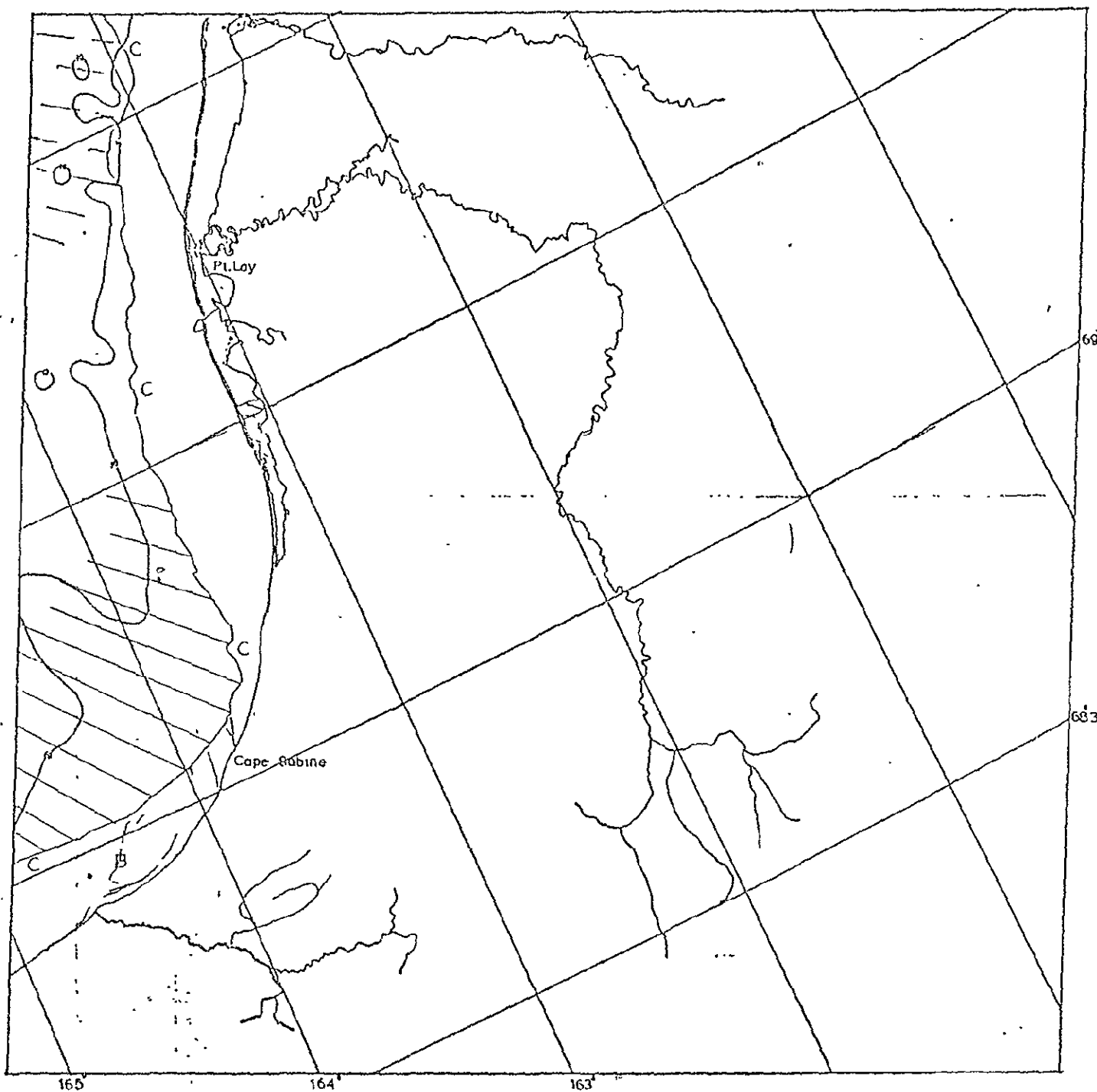
E-2130-21524-7  
 1 JUNE 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

E-2131-21564-7  
2 JUNE 1975

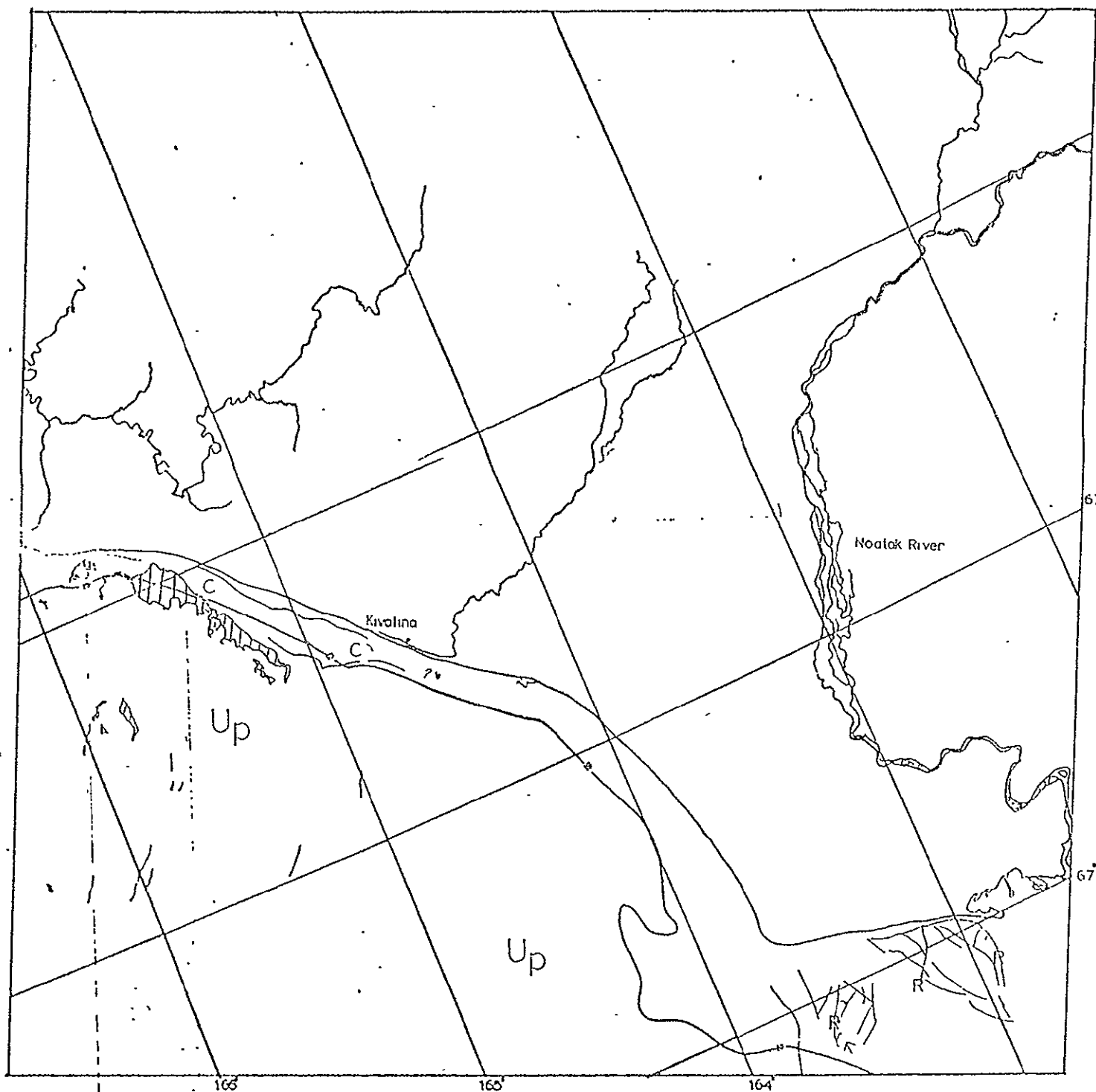
CHUKCHI SEA



165 164 163  
KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

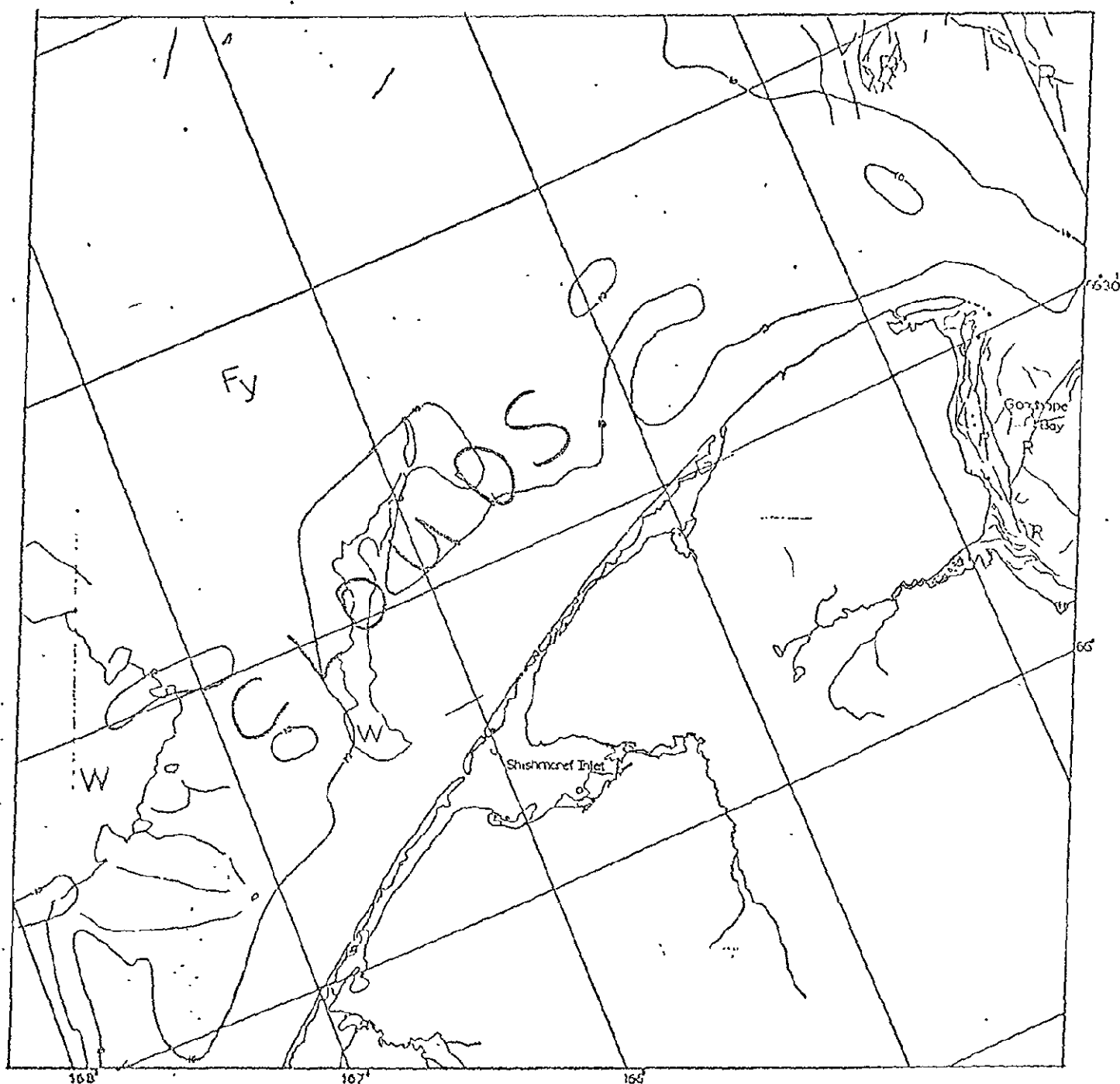
CHUKCHI SEA

E-2131-21573-7  
2 JUNE 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

E-2131-21580-7  
2 JUNE 1975

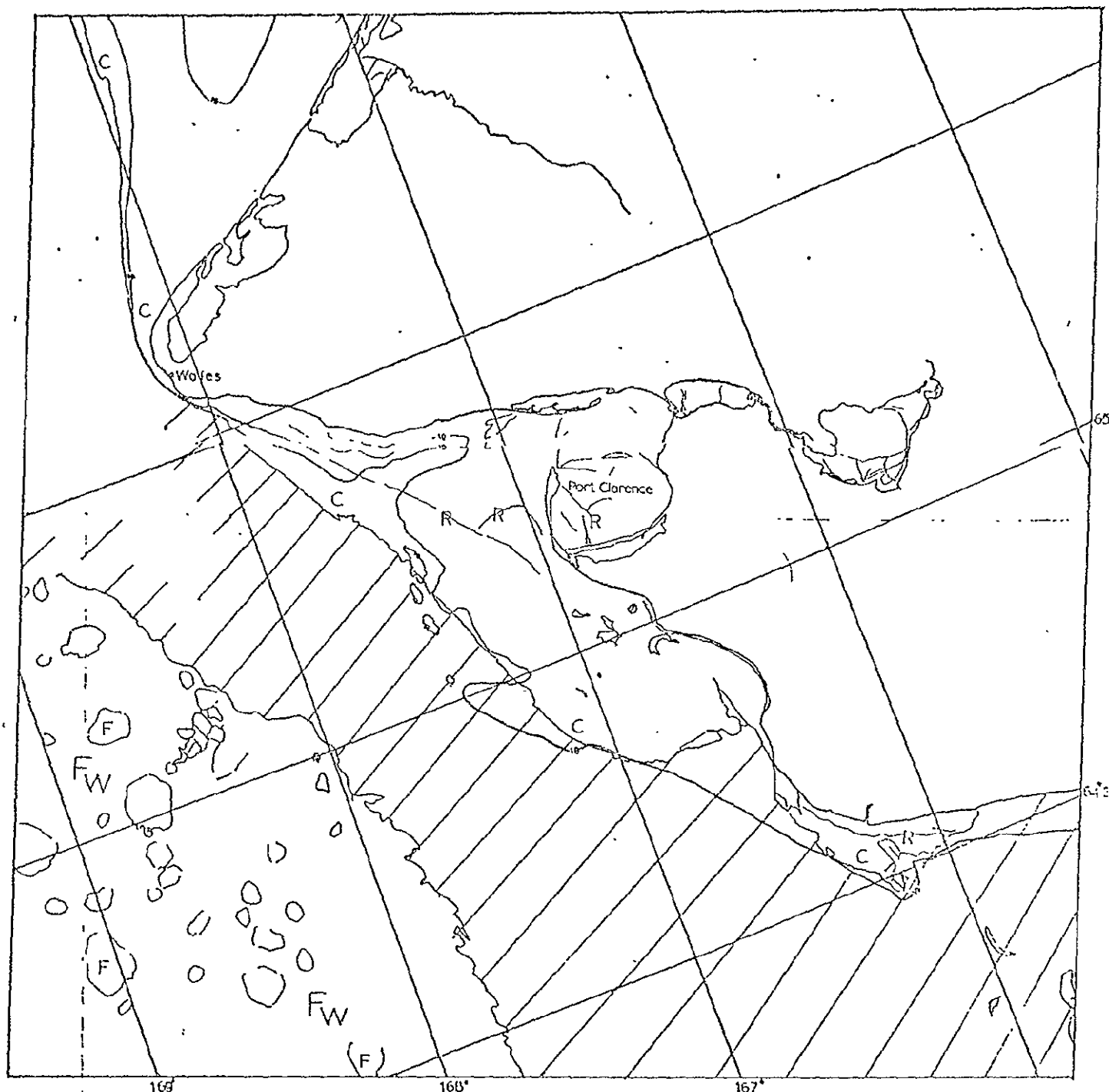


168° 167° 166°  
 KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2131-21502-7  
 2 JUNE 1975





169° 168° 167°  
 KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

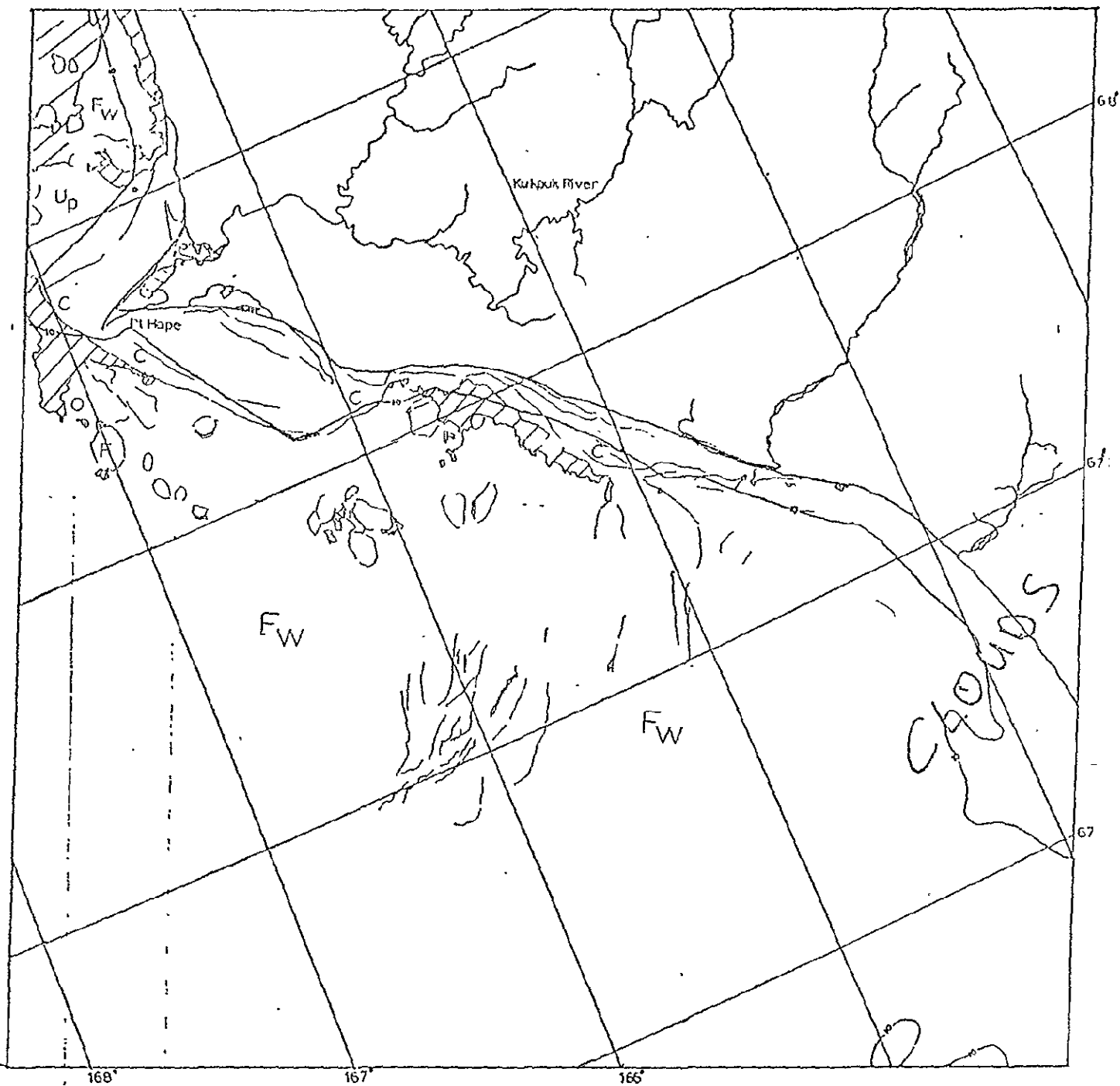
CHUKCHI SEA

E-2131-21585-7  
 2 JUNE 1975



CHUKCHI SEA

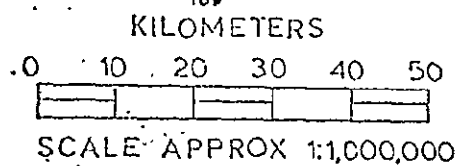
E-2132-22032-7  
3 JUNE 1975



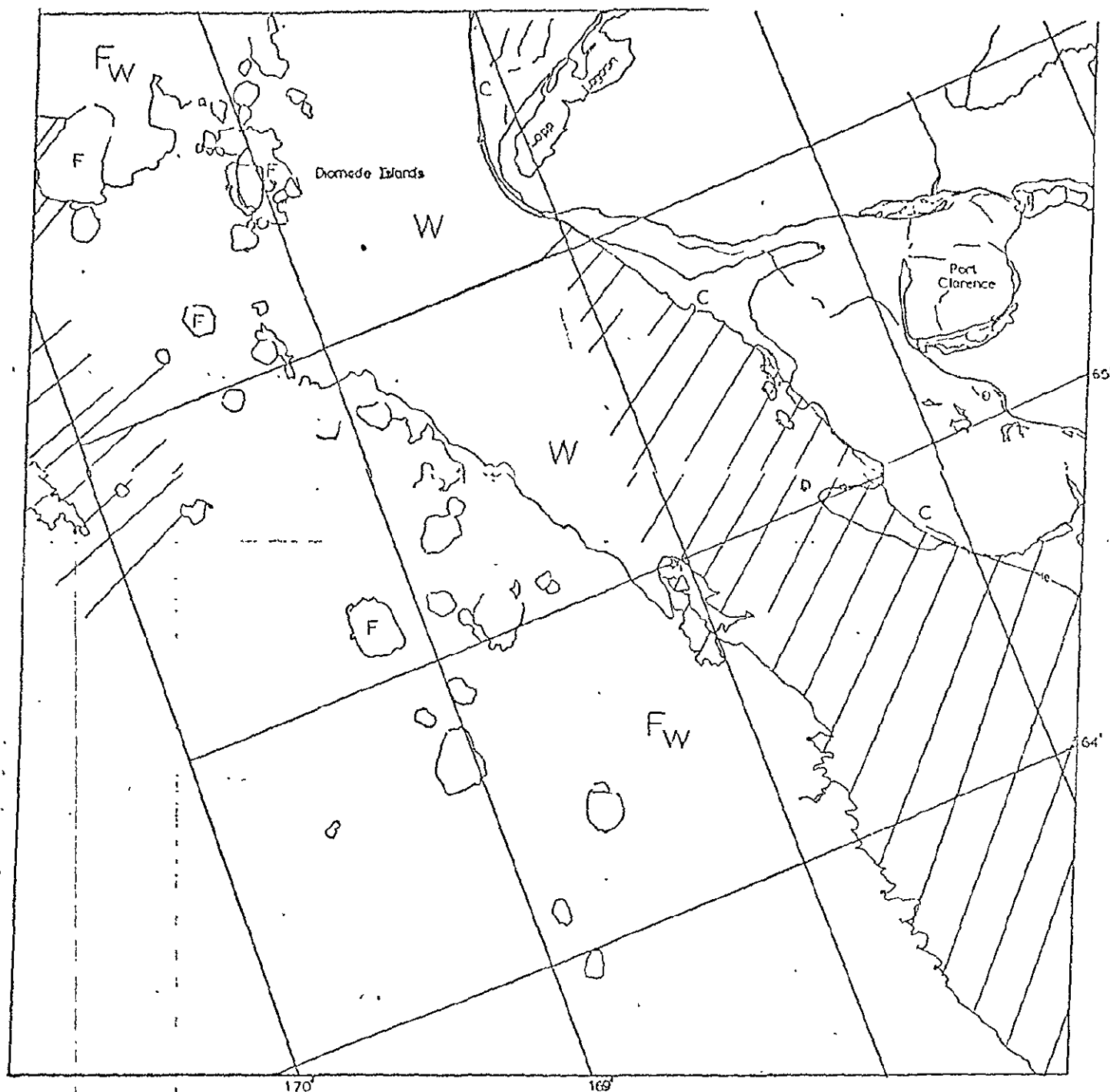
0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2132-22034-7  
 3 JUNE 1975

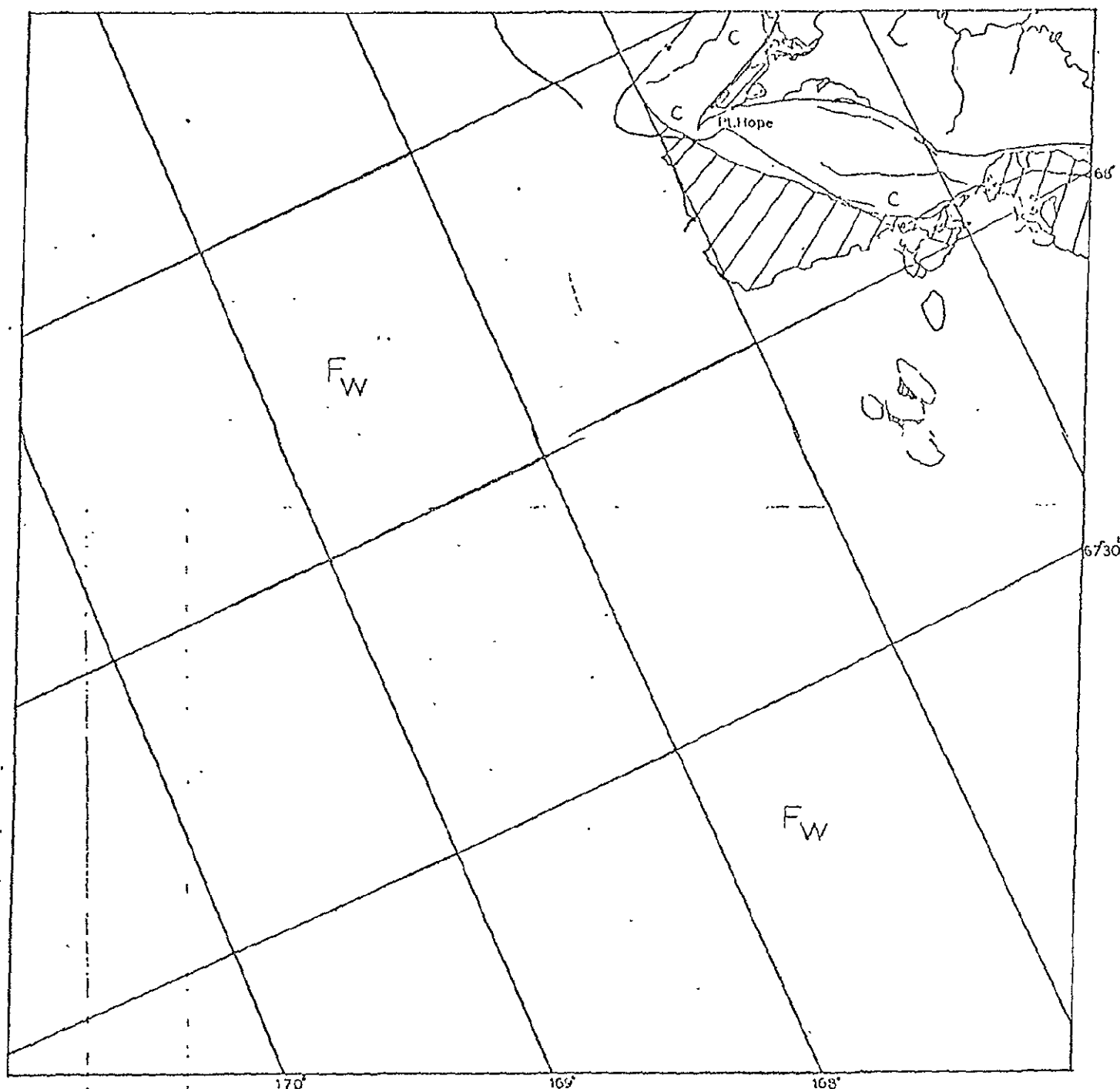


E-2132-22041-7  
3 JUNE 1975



E-2132-220-13-7  
3 JUNE 1975

CHUKCHI SEA

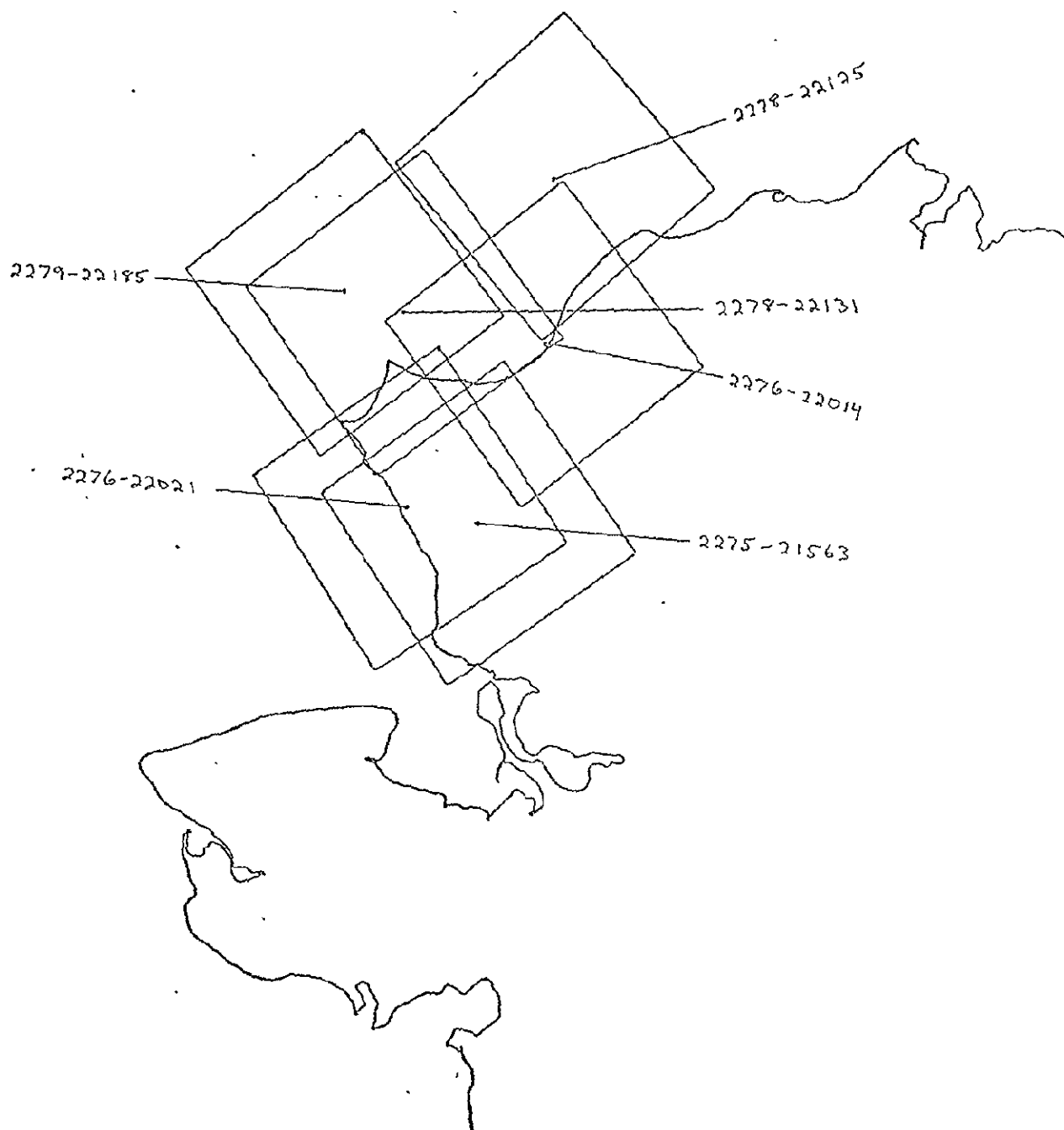


0 10 20 30 40 50  
 KILOMETERS  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2134-22151-7  
 5 JUNE 1975

CHUKCHI SEA  
21 OCTOBER-8 NOVEMBER 1975  
Cycle 2272-2290



Scenes 2275-21563

2276-22014 } adjacent pair  
2276-22021 }

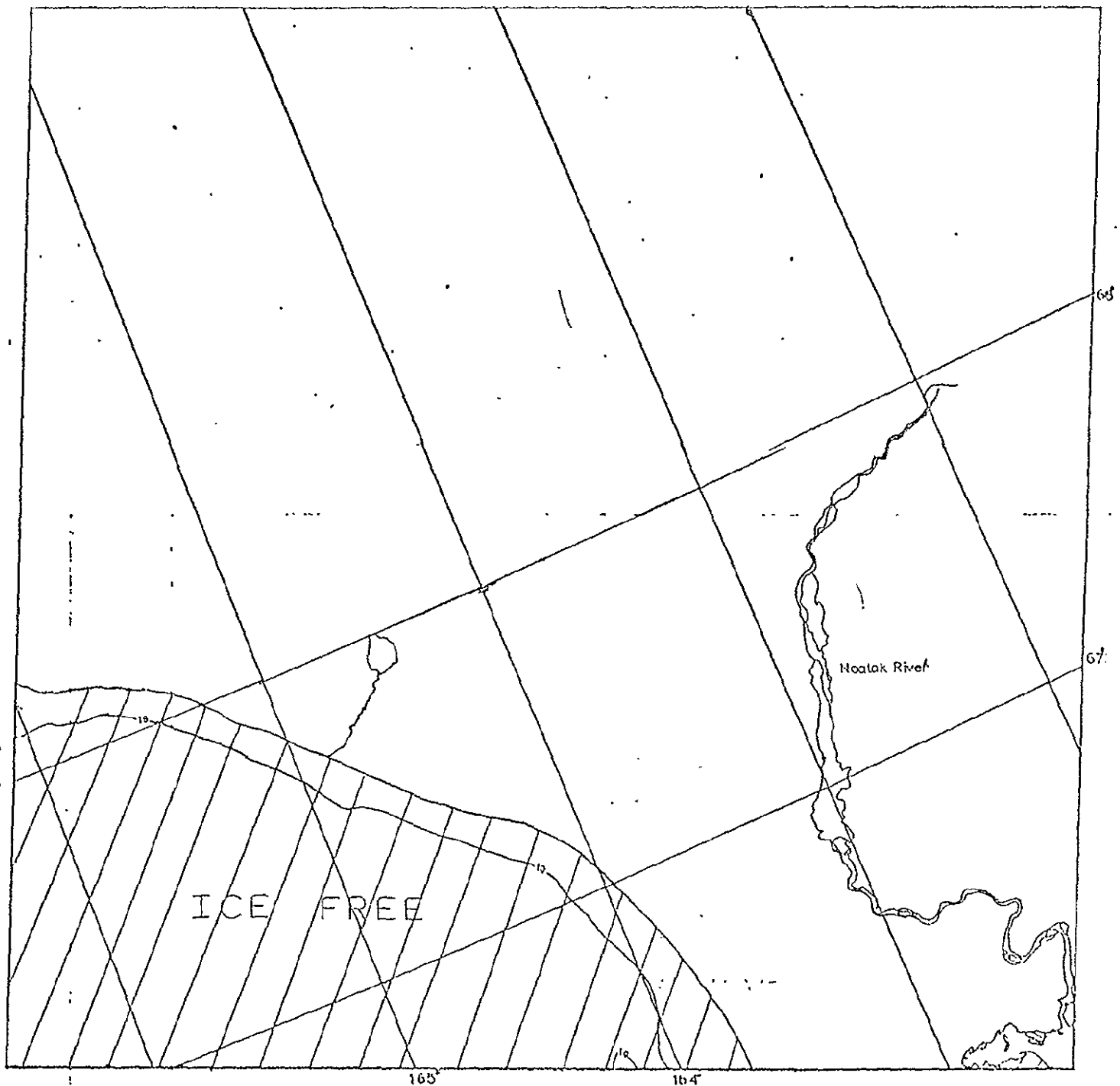
2278-22125 } adjacent pair  
2278-22131 }

2279-22185

These scenes show the Cape Lisburne area for October 24-28, 1975. The ice in these scenes is from young to new and is repeatedly being broken up with new ice forming in the newly-created voids. Cloud patterns indicate shifting wind systems responsible for fragmentation of the ice. Ice piling in the near shore areas has been limited to locations very close to the break. No large shear or pressure ridges have been formed.

ORIGINAL PAGE IS  
OF POOR QUALITY



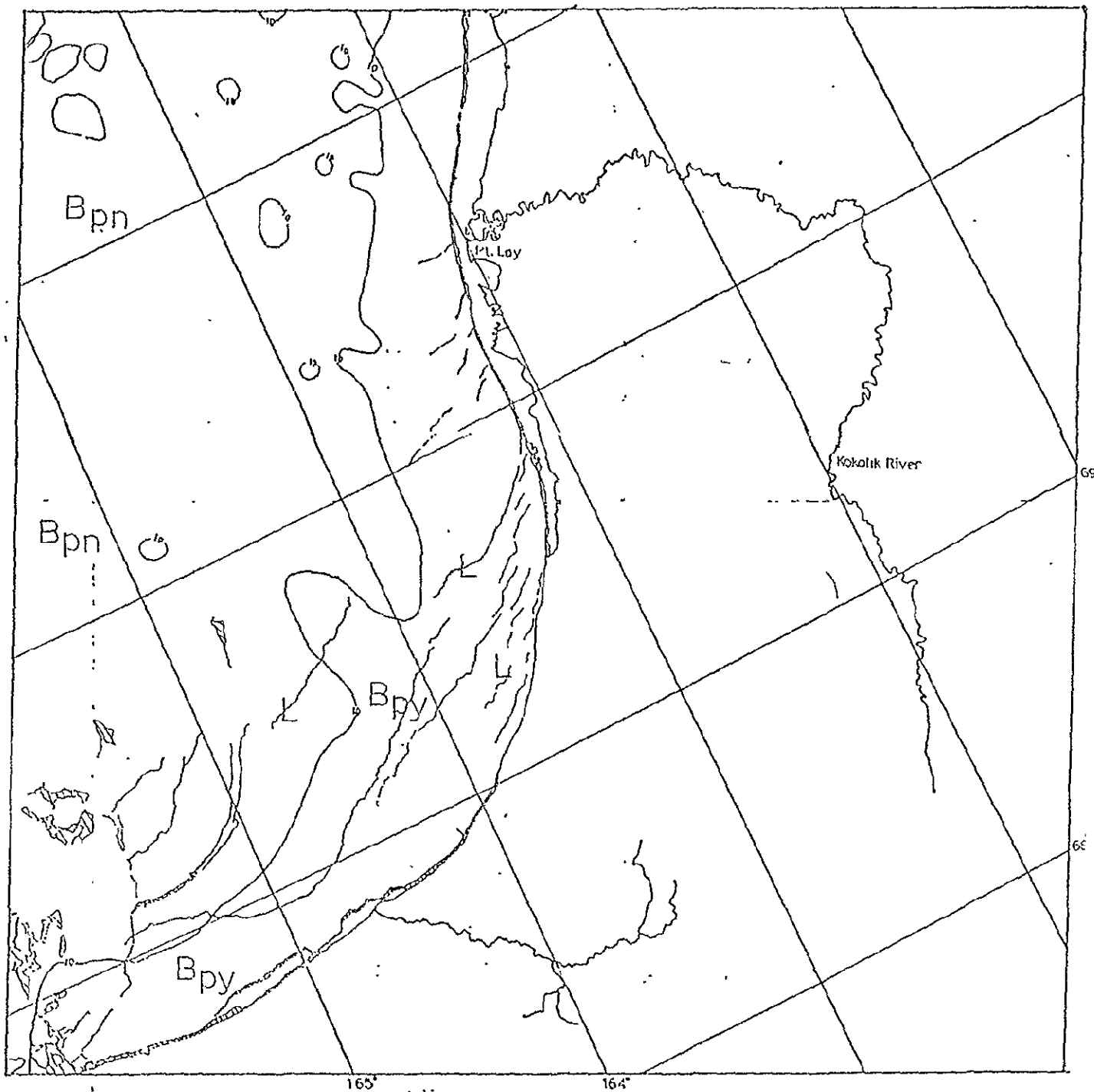


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2275-21553-7  
24 OCT. 1975

241

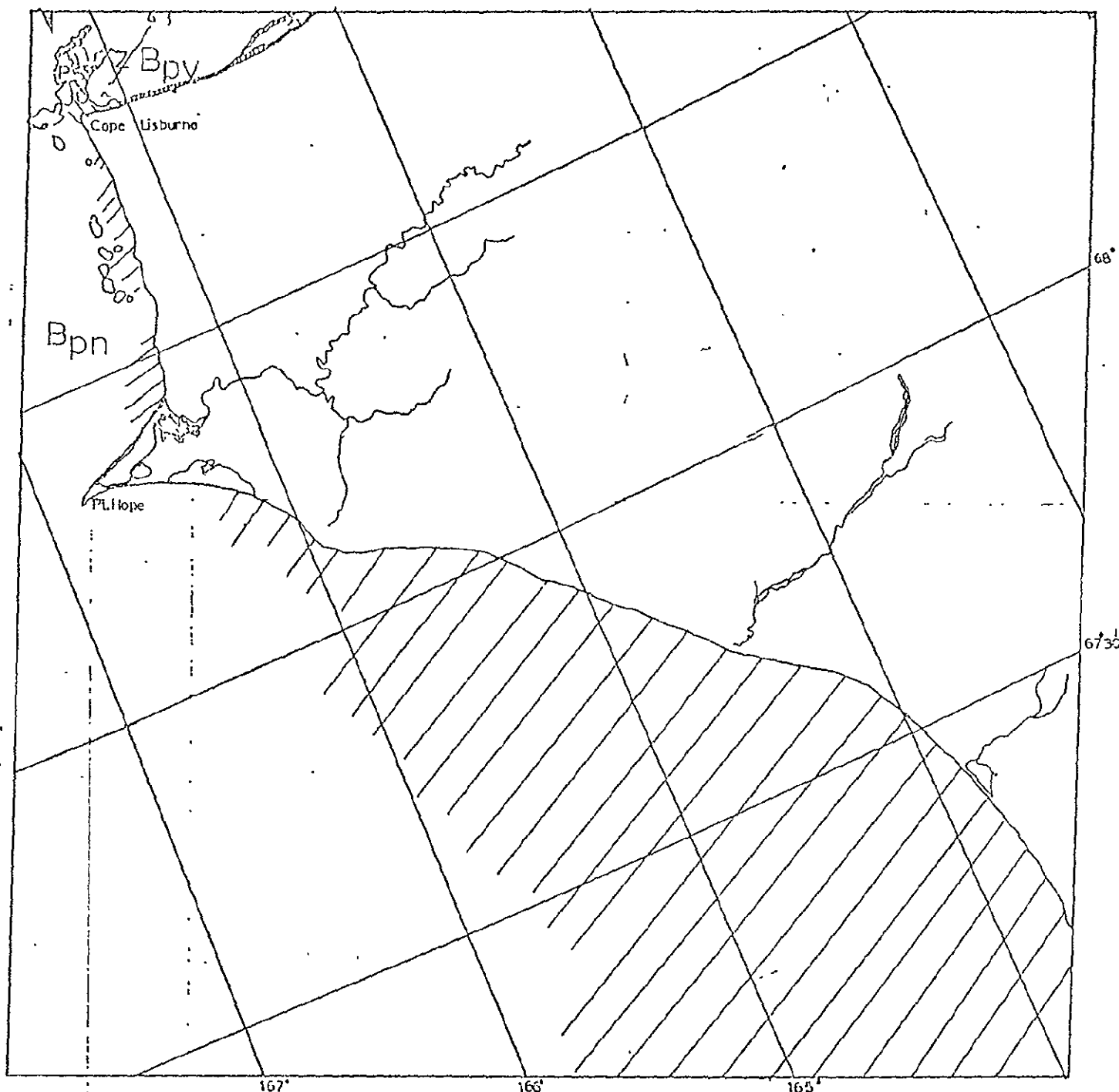


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2276-22014-7  
25 OCT. 1975

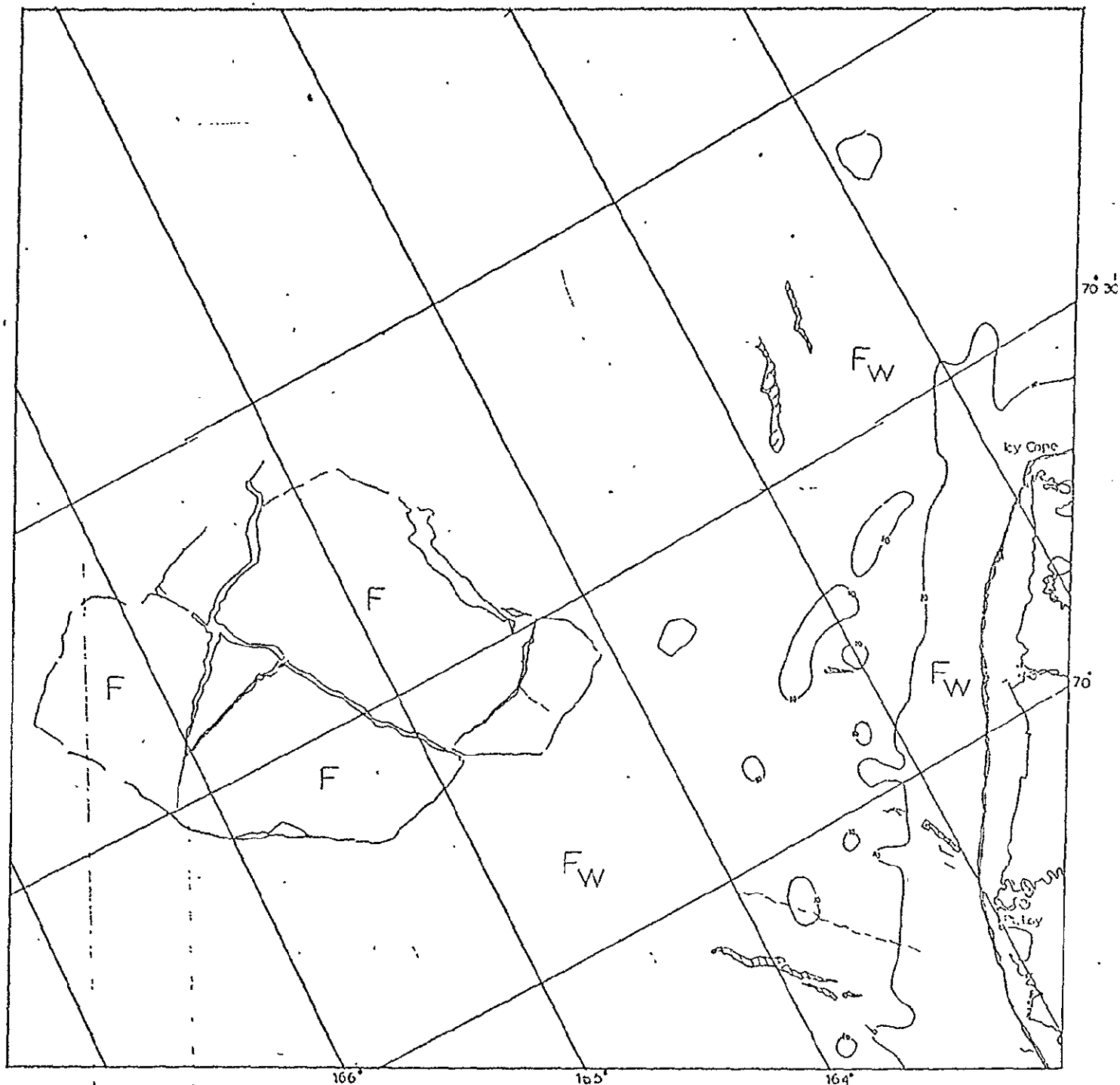
242



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

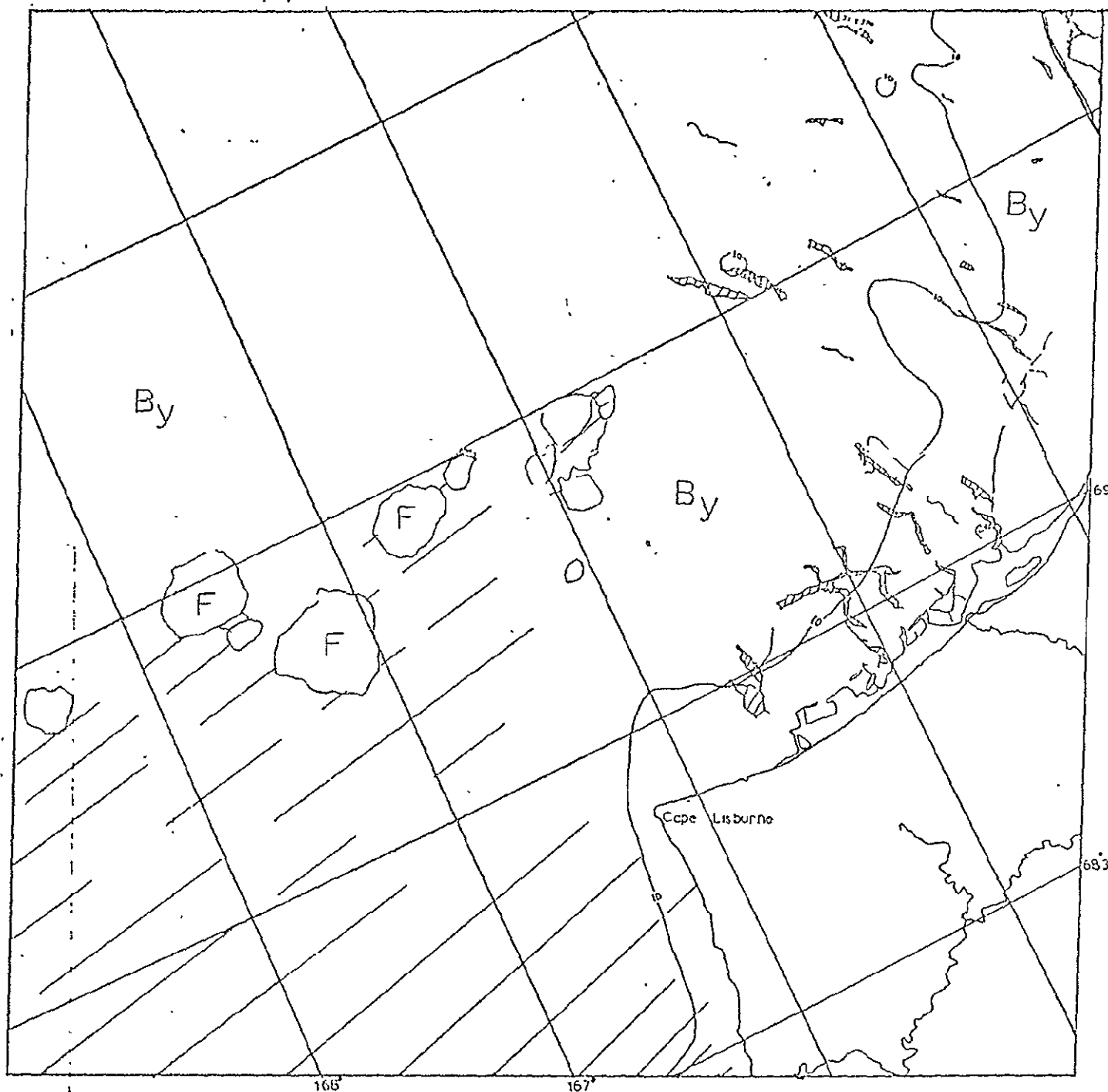
E-2276-2203-7  
 25 OCT. 1975



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

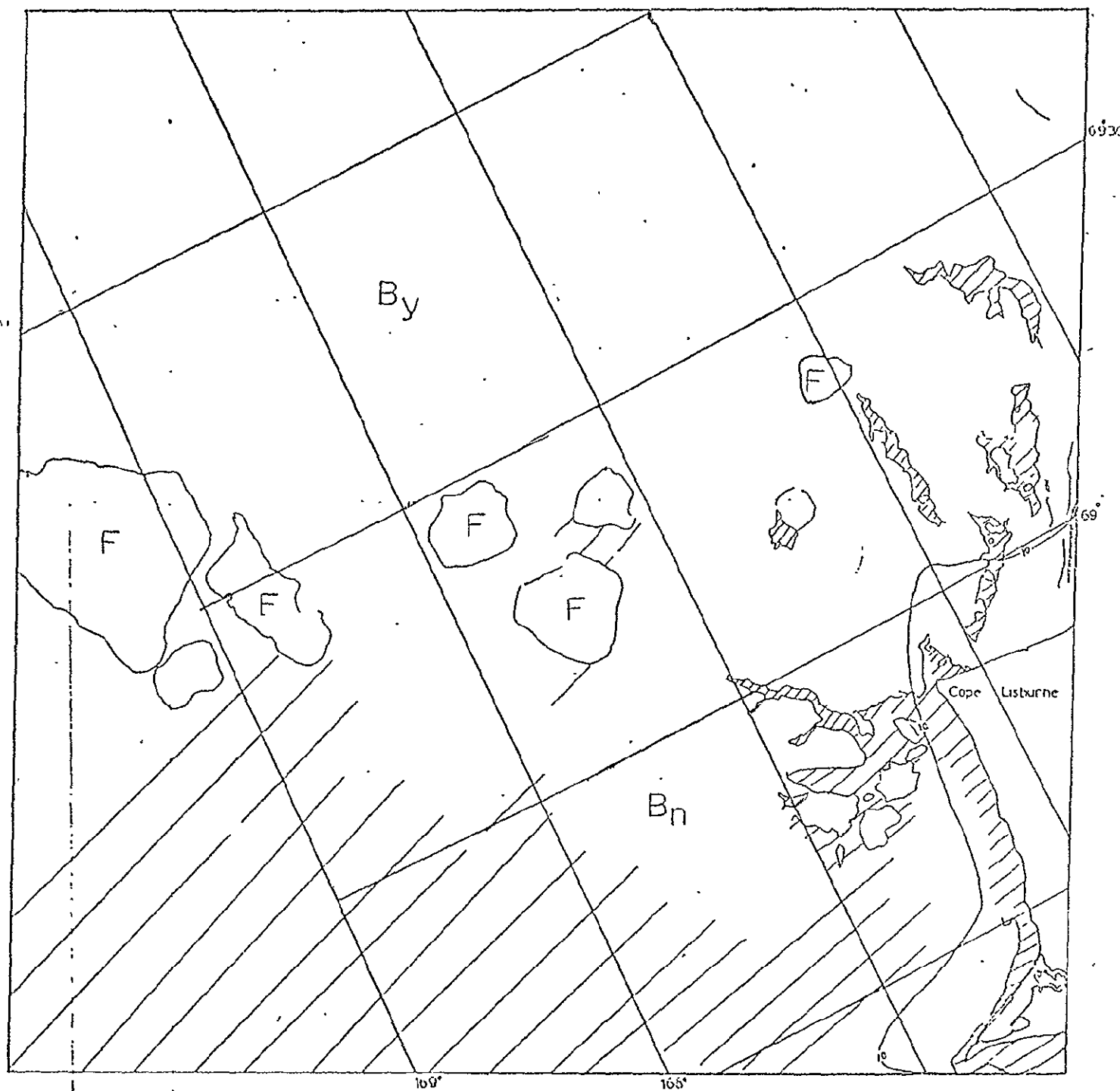
E-2278-22125-7  
 27 OCT. 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

E-2278-22131-7  
27 OCT. 1975

CHUKCHI SEA



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

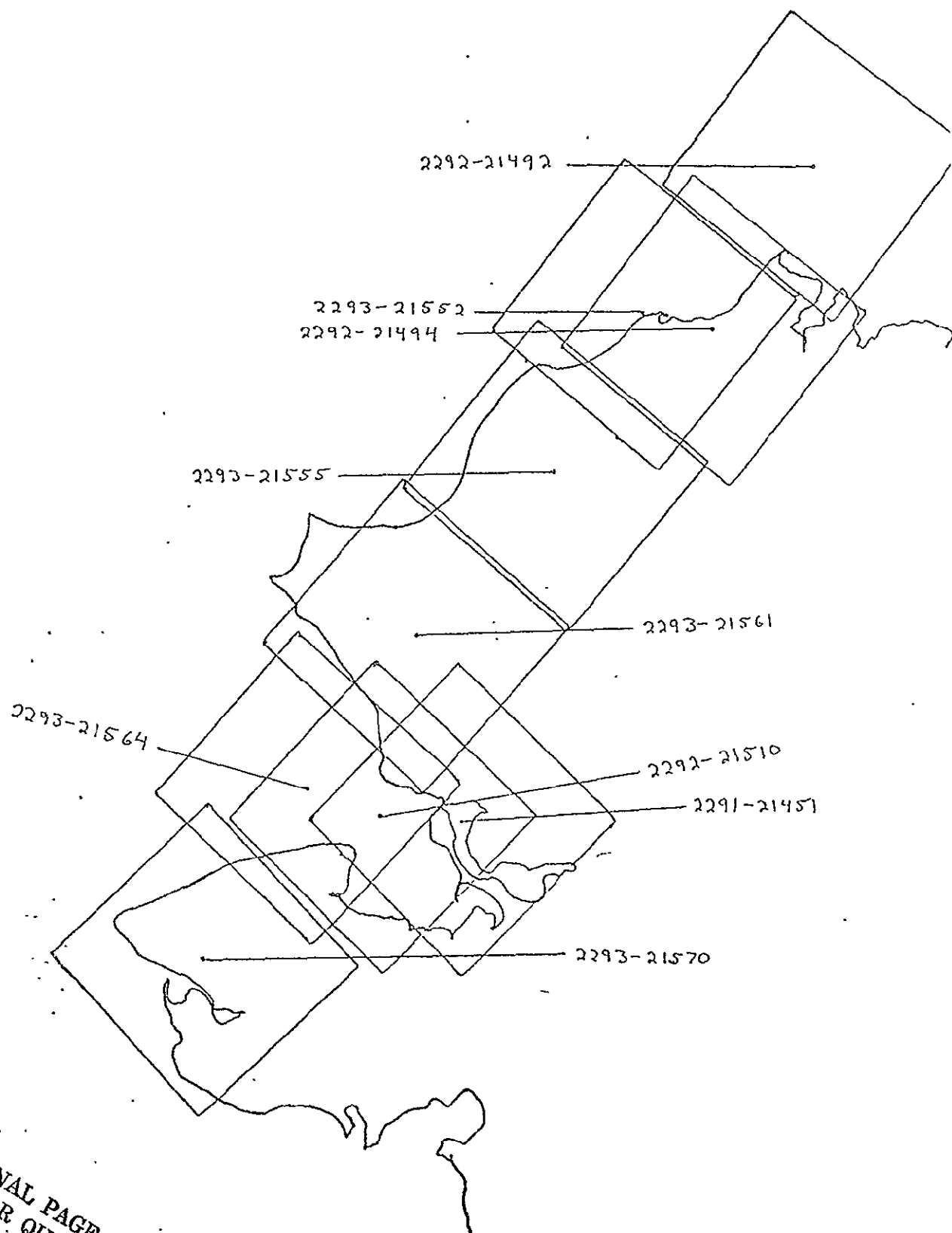
CHUKCHI SEA

E-2279-22185-7  
 28 OCT. 1975

# CHUKCHI SEA

9-26 NOVEMBER 1975

Cycle 2291-2308



ORIGINAL PAGE IS  
OF POOR QUALITY

Scenes 2291-21451

2292-21492 } adjacent pair  
2292-21494 }

2292-21510

2293-21552 )

2293-21555 |

2293-21561 } group of 5 adjacent scenes

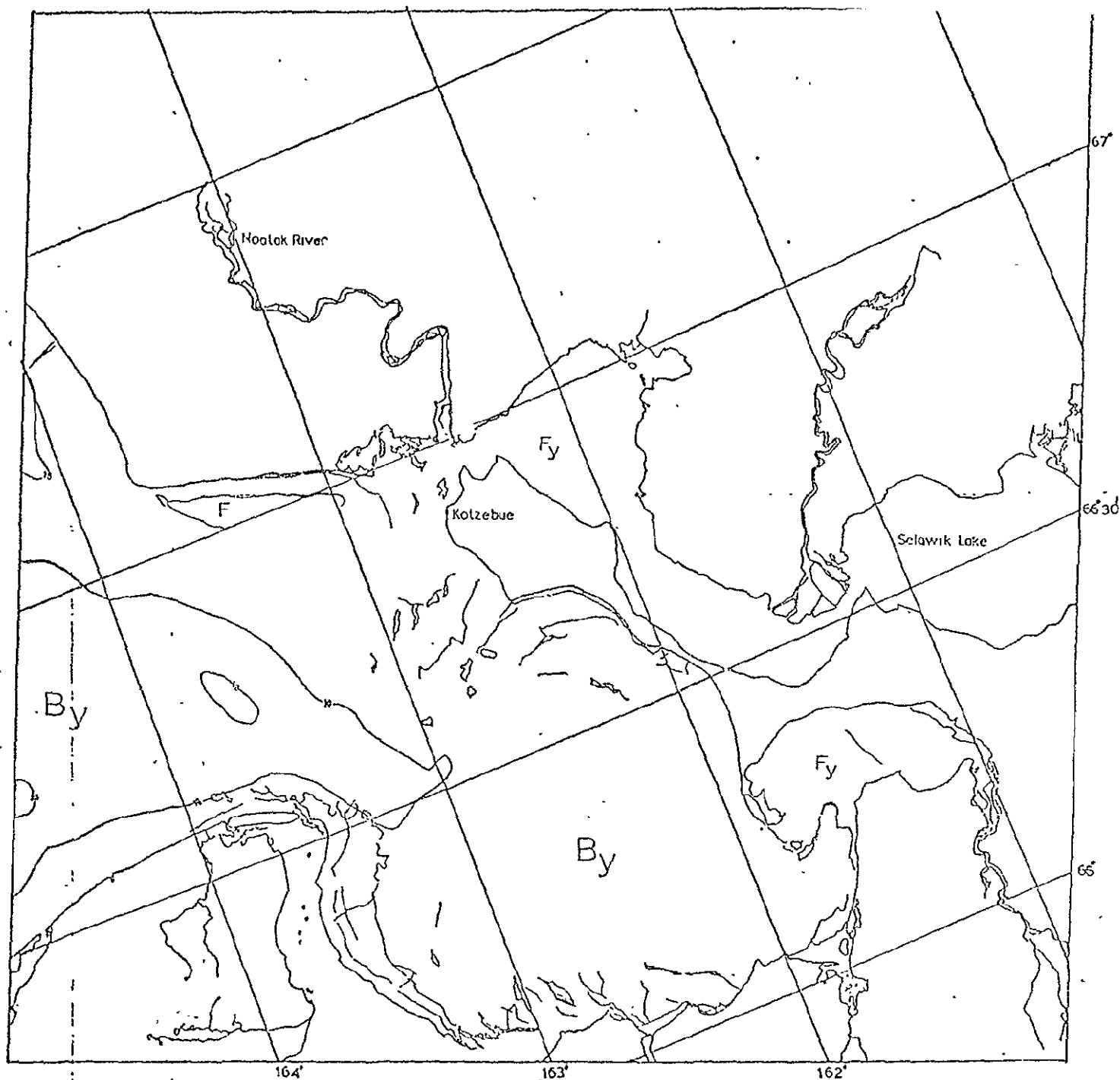
2293-21564 }

2293-21570 }

These scenes show the Chukchi Coast of Alaska for the period of November 9-11, 1975 between Barrow and Nome. At this time large expanses of contiguous ice can be found along the coast. However, there is no evidence of large grounded ridge systems that would be required to produce ice which would remain shore fast for the remainder of the winter season.

ORIGINAL PAGE IS  
OF POOR QUALITY

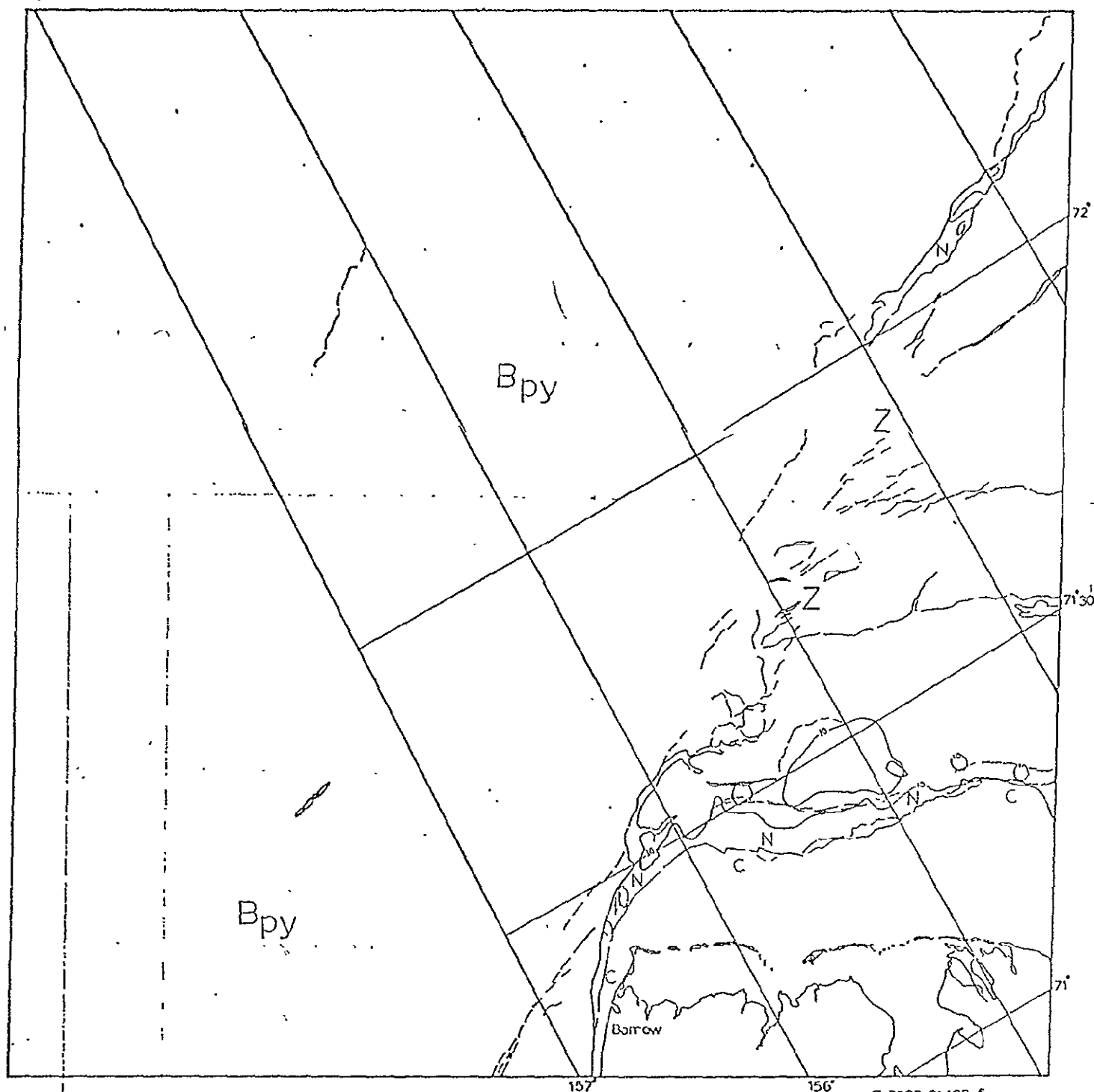




KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

E-2291-21451-7  
 9 Nov. 1975

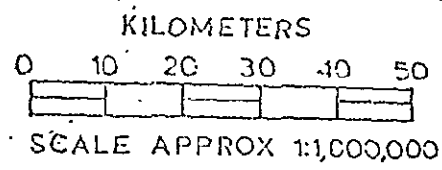
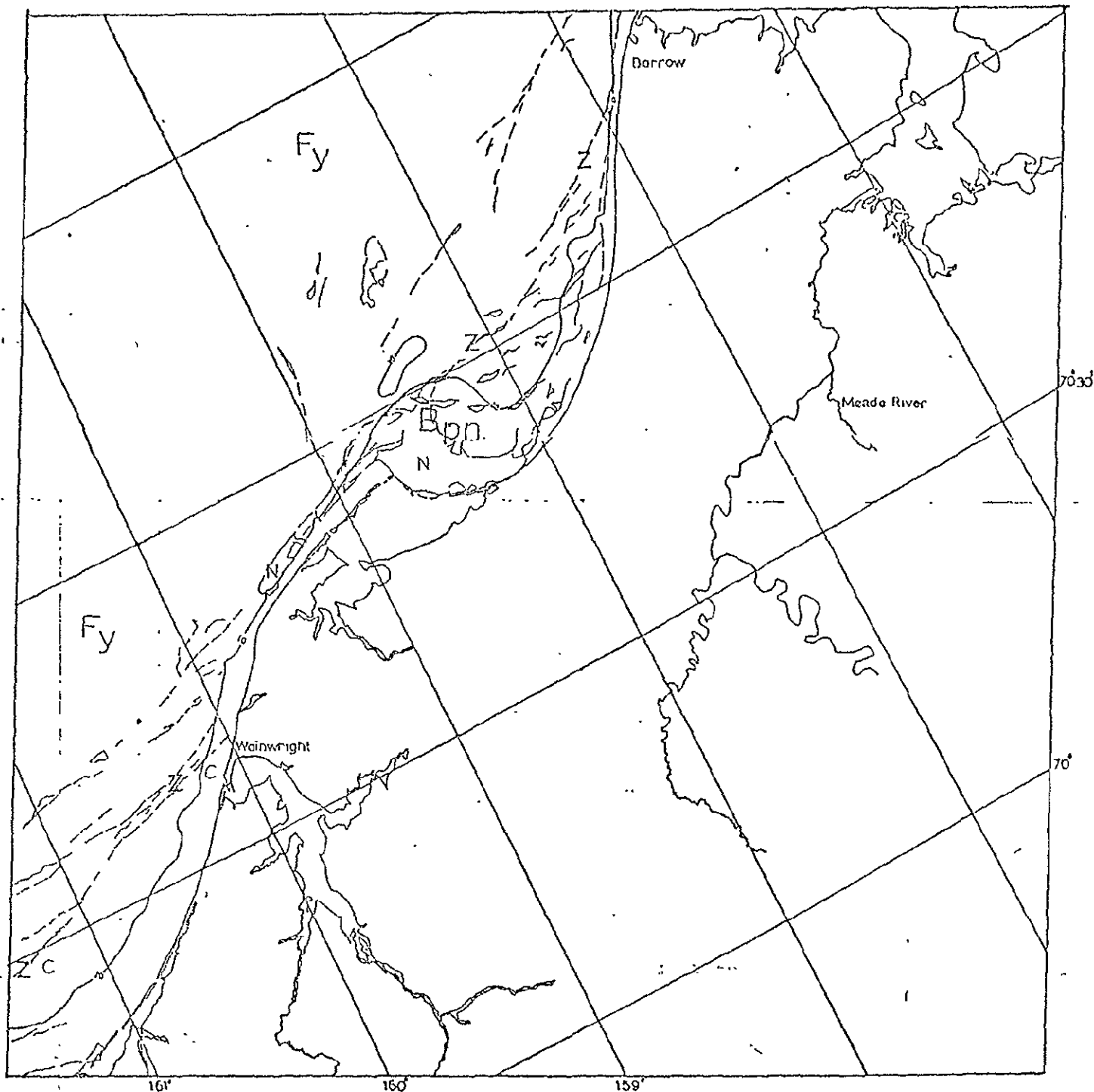
CHUKCHI SEA



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

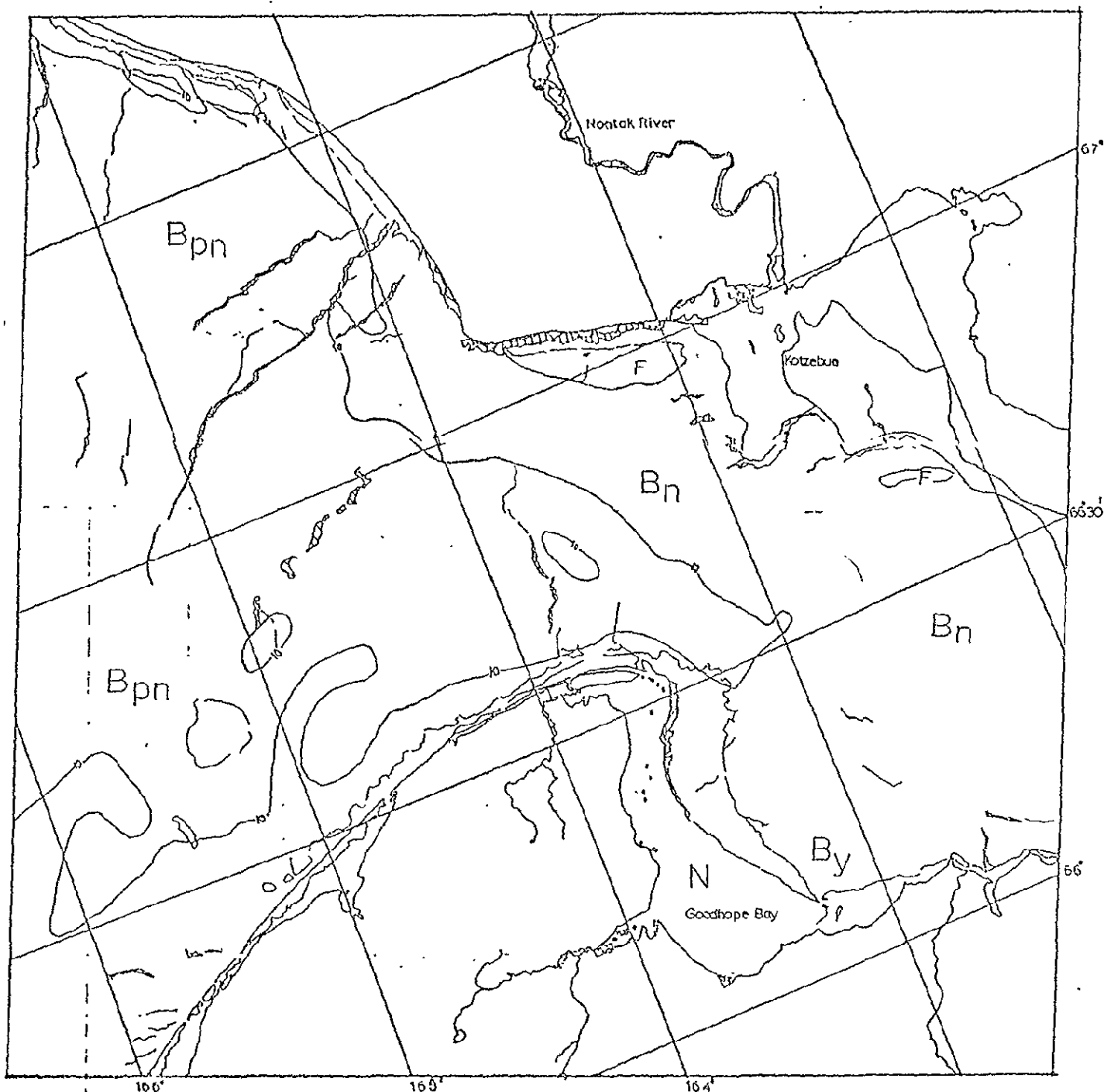
CHUKCHI SEA

E-22332-21493-5  
10 NOV. 1975



CHUKCHI SEA

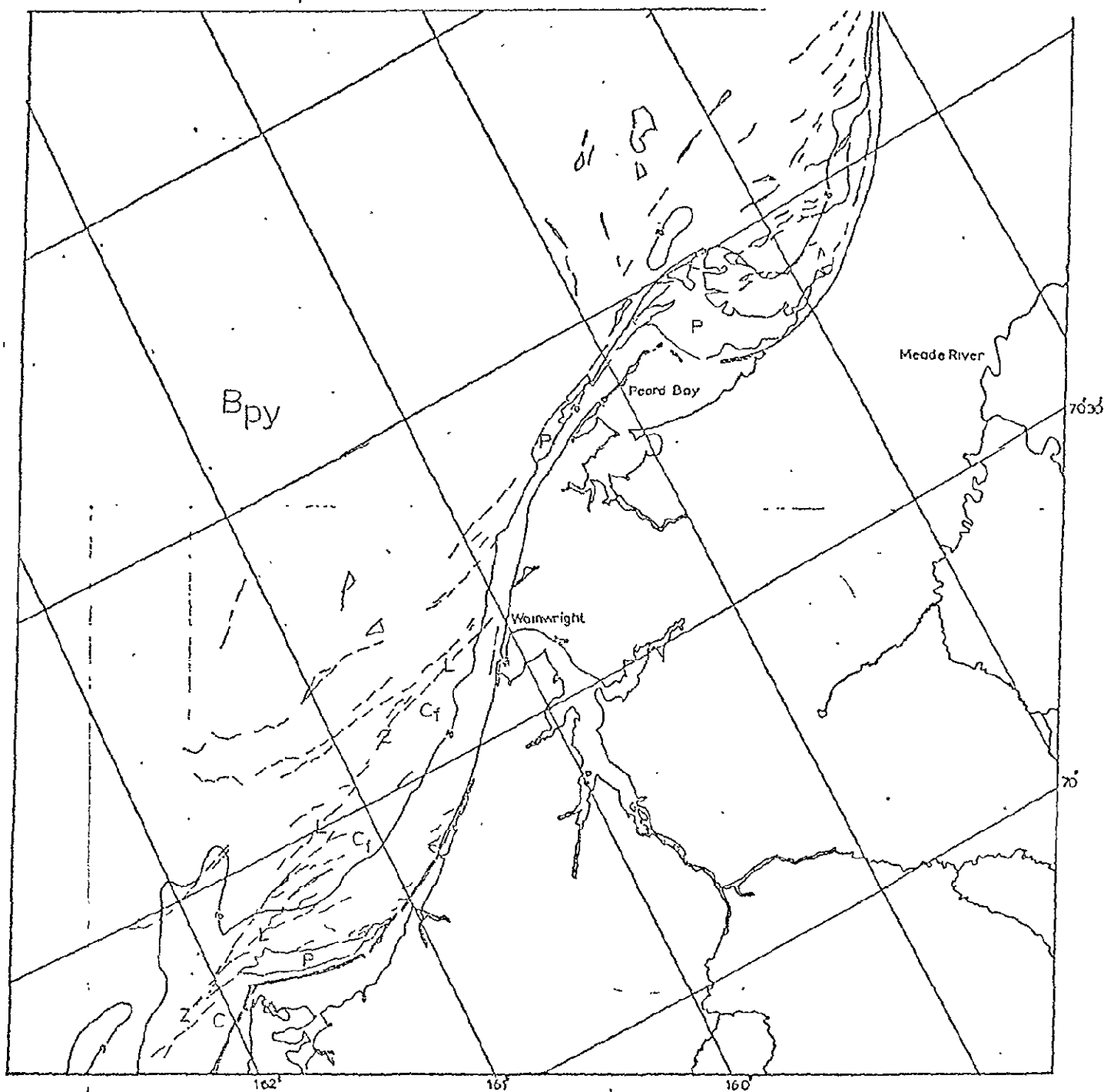
E-2292-21494-5  
10 NOV. 1975



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2292-21510-7  
10 NOV. 1975

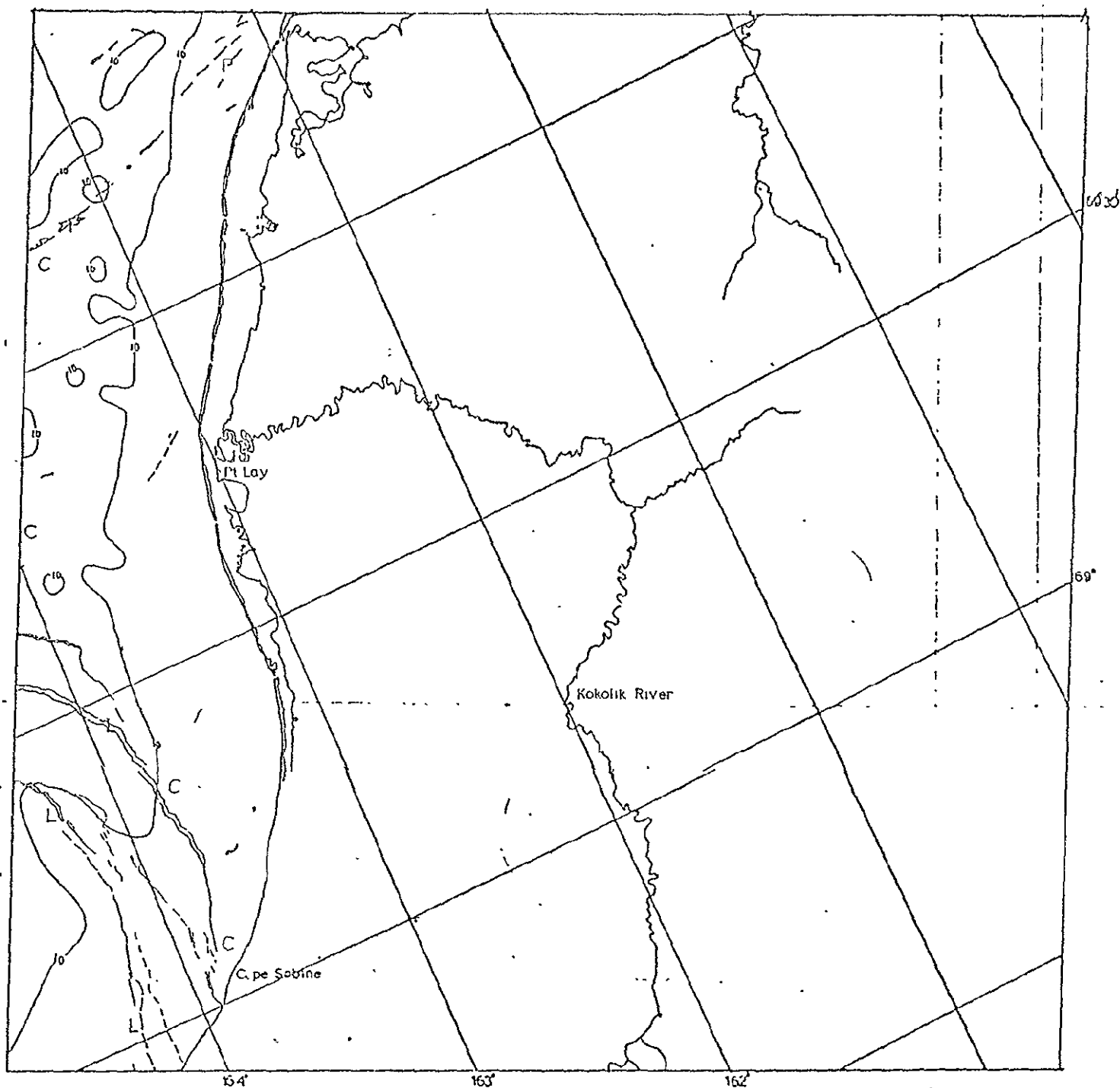


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

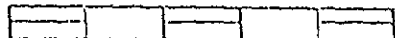
E-2293-21552-5

11 NOV. 1975



KILOMETERS

0 10 20 30 40 50

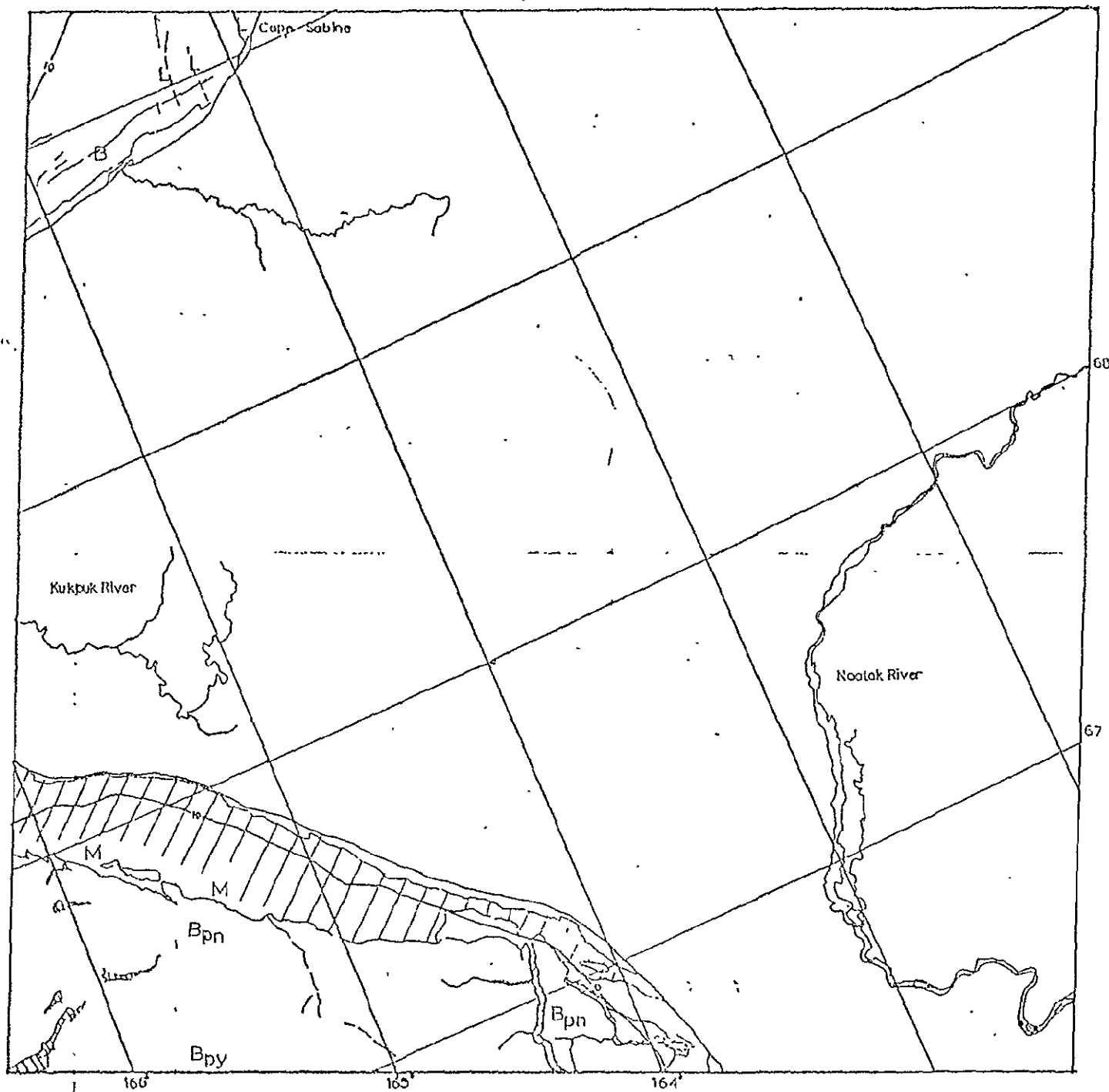


SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2293-21555-5

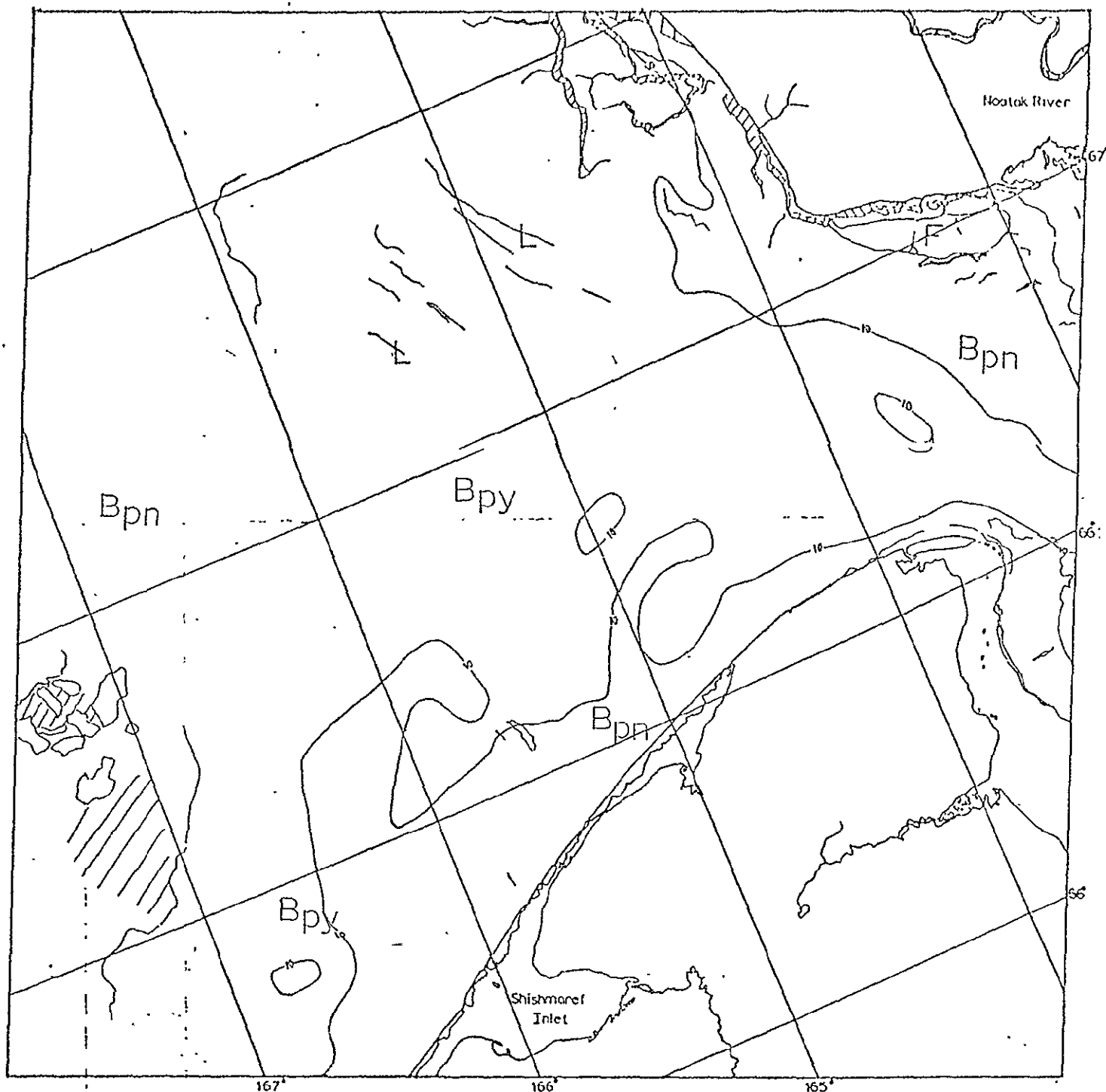
11 NOV. 1975



0 10 20 30 40 50  
 KILOMETERS  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2293-2561-7  
 11 NOV. 1975

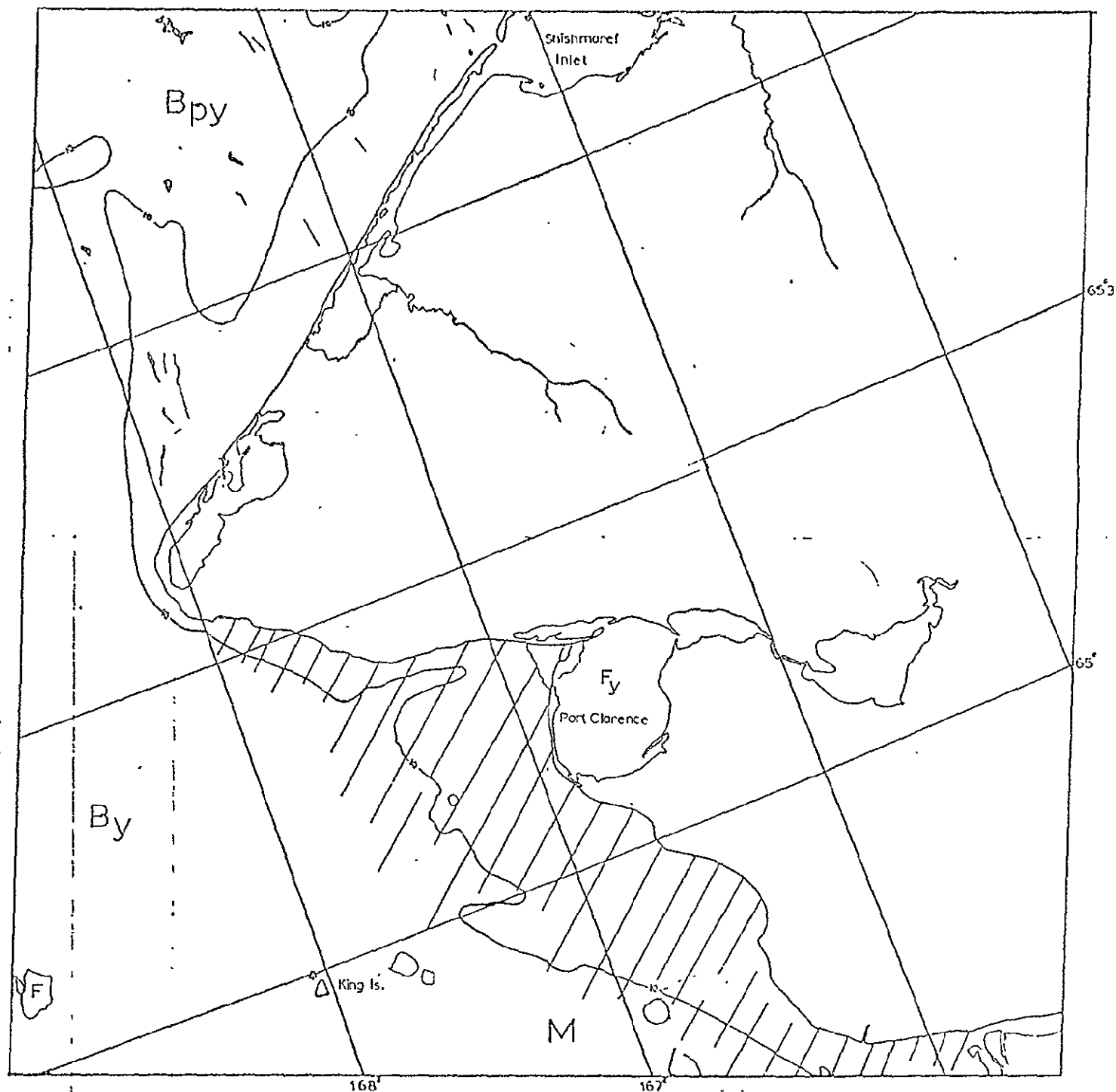


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2293-21564-7  
11 NOV. 1975





KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

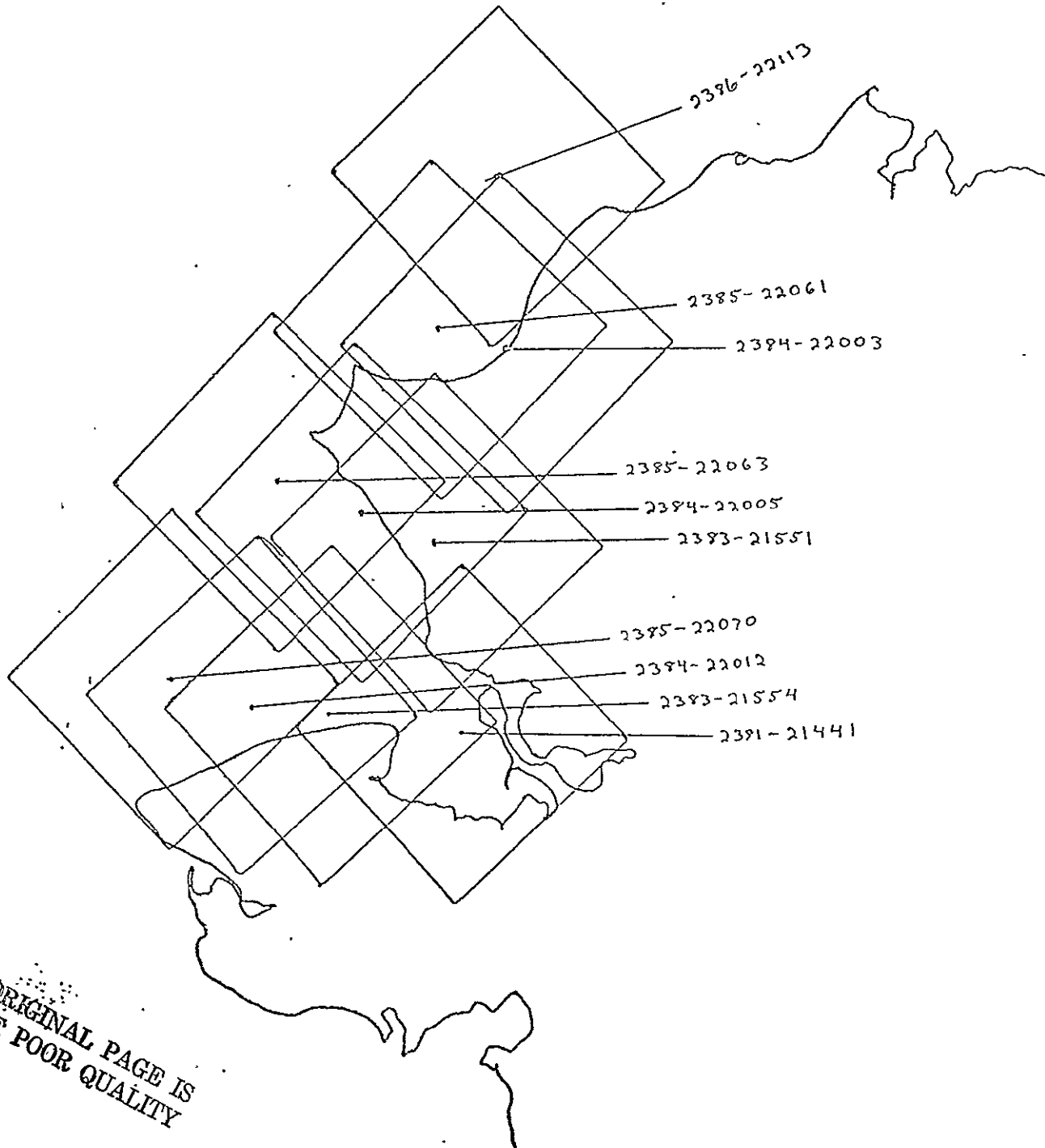
E-2293-21570-7  
11 NOV. 1975

CHUKCHI SEA

# CHUKCHI SEA

6-23 FEBRUARY 1976

Cycle 2381-2398



Scenes 2381-21441

2383-21551 } adjacent pair  
2383-21554 }

2384-22003 } adjacent triplet  
2384-22005 }  
2384-22012 }

2385-22061 } adjacent triplet  
2385-22063 }  
2385-22070 }

2386-22113

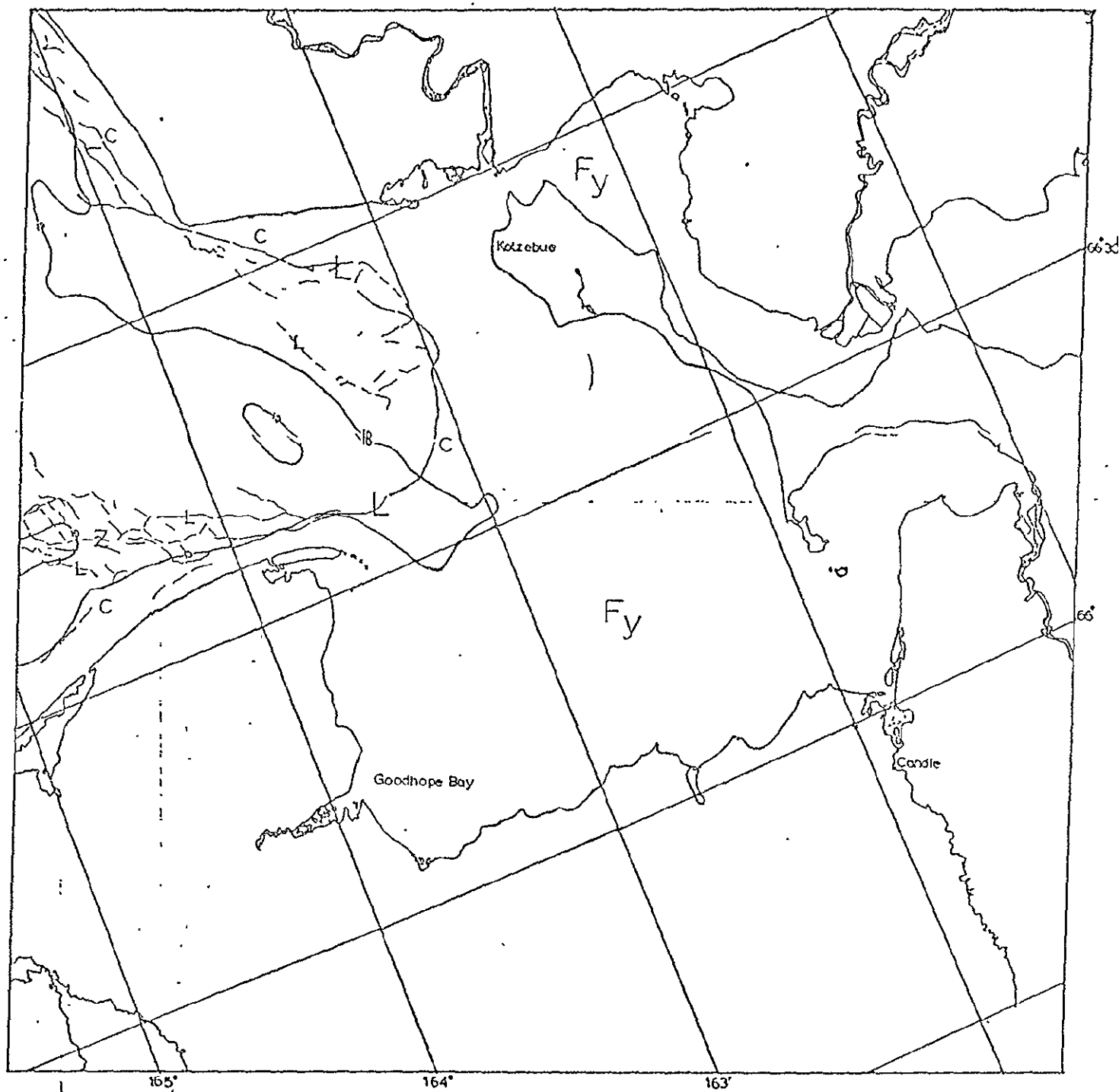
These scenes show the Kotzebue sound region between Point Lay and Bering Strait for the period February 7-12, 1976.

At this time the inner part of Kotzebue sound is covered with smooth first-year ice. There is a sideways "U"-shaped indentation of pressured ice protruding into the sound with associated shearing effects along its arms. The three sets of adjacent images show dynamic processes at work in the lower Chukchi sea: Winds appear to be forcing the ice southward through Bering Strait. Associated with this is a large polynya south of Point Hope. However, the open water in the polynya is freezing to the young ice almost as fast as it is formed. Immediately south of this polynya is a funnel-shaped area of highly pressured ice which shows considerable compaction even within the one day observation period between the second and third adjacent scene triplets.

Immediately south (50 km) of the "spout" of the funnel is a large north-south shear ridge hummock field extending northward from Cape Prince of Wales. It would appear that this large feature has been created by the construction of large massive shear ridges over shoals in this area with the result that the ridges easily become grounded and stabilized. At this time, a line of shear can be traced northward from Cape Prince of Wales, past the ridge system, and up the westward side of the funnel.

To the north, ice appears to be shearing past Point Hope, leaving an accumulation of ice on the shoals just to the north of Point Hope. North of Cape Lisburne a smooth apron of first year ice extends to approximately the 10-fathom contour. Approaching Blossom Shoals, there are increasing indications of large ridges along the seaward edge of the apron ending in a large hummock field at Blossom Shoals.

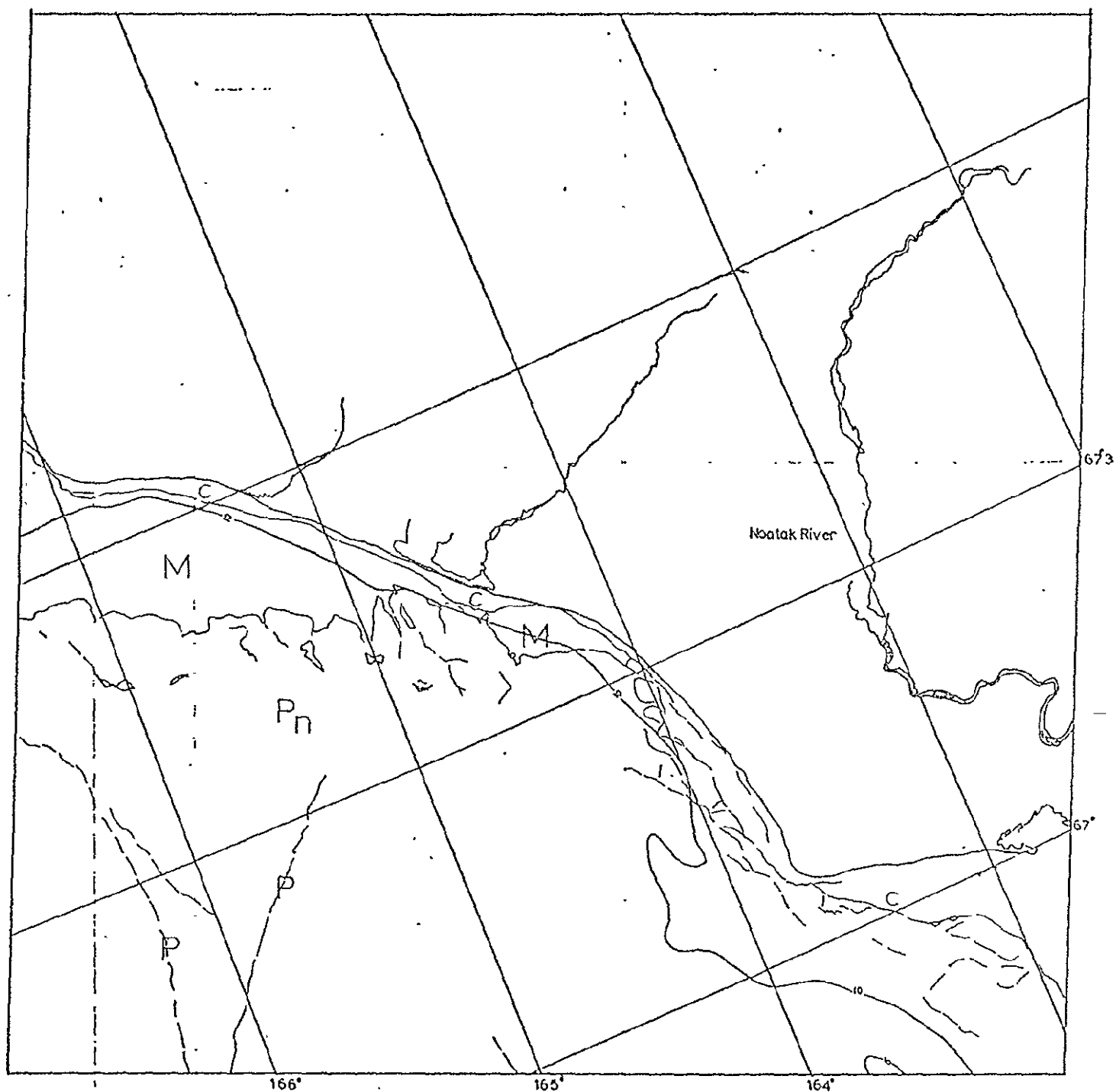
ORIGINAL PAGE IS  
OF POOR QUALITY



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

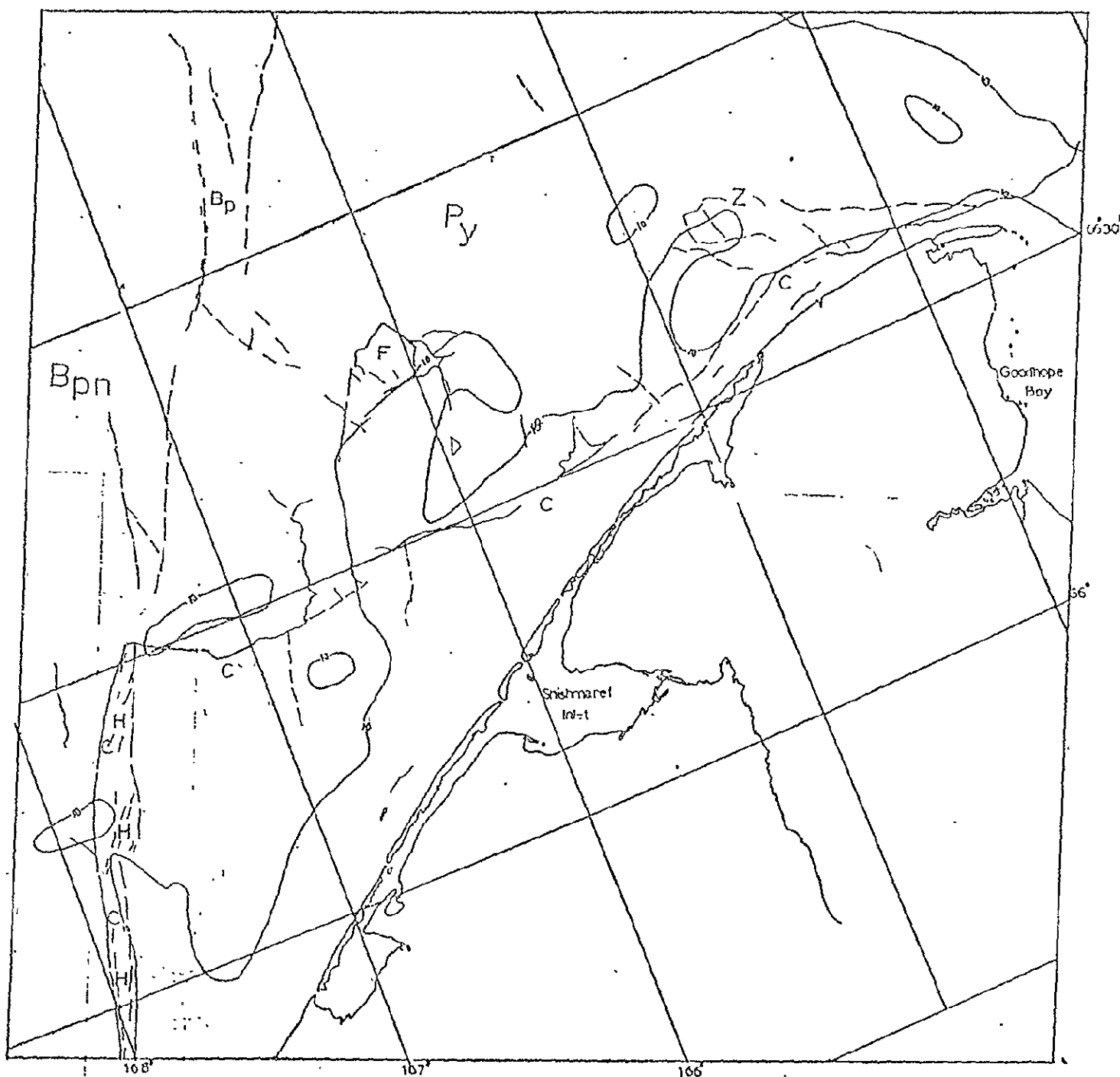
E-2381-21441-7  
 7 FEB. 1976



0 10 20 30 40 50  
KILOMETERS  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

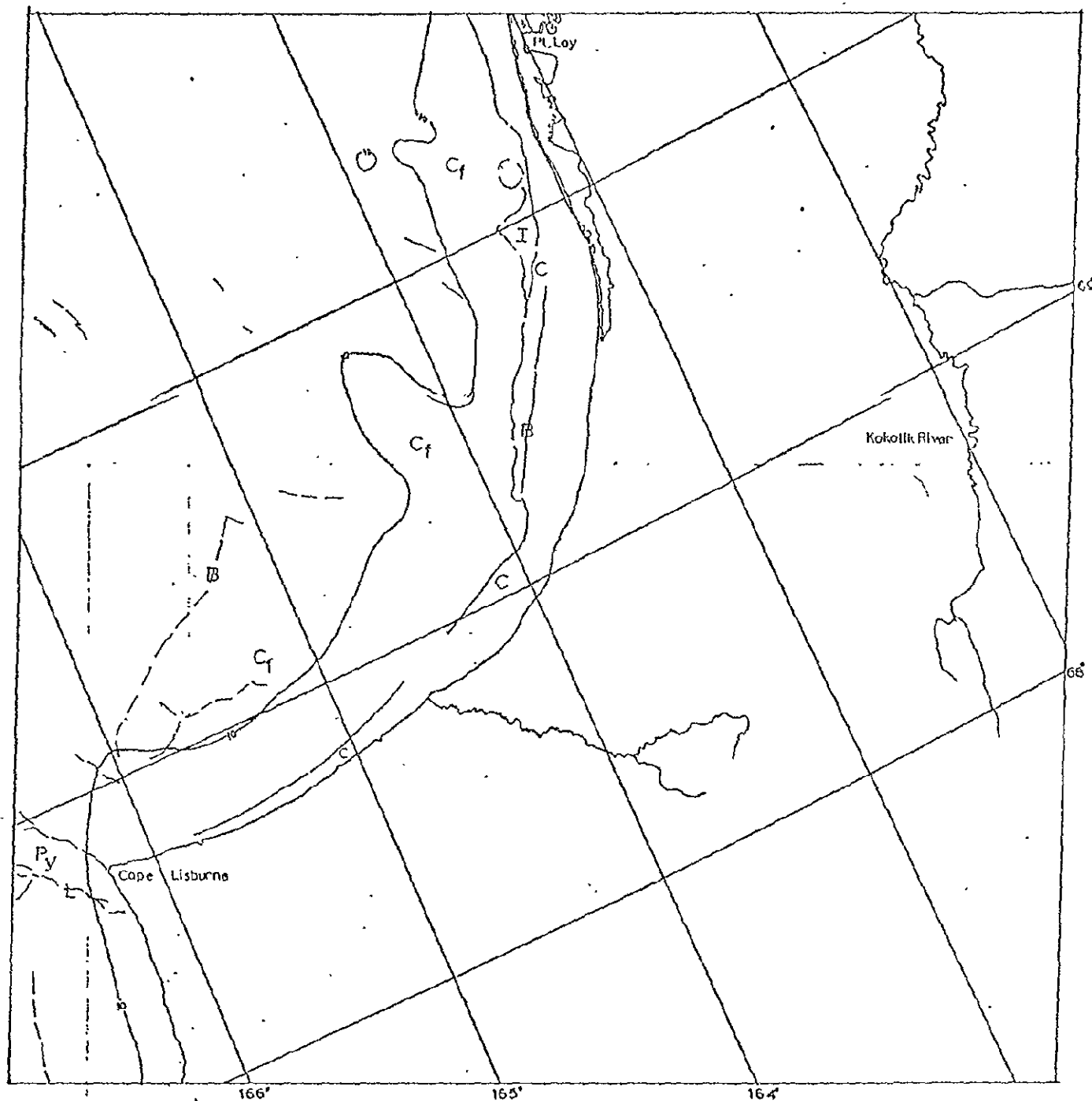
E-2393-21551-7  
9 FEB. 1976



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2383-21554-7  
 9 FEB. 1976



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

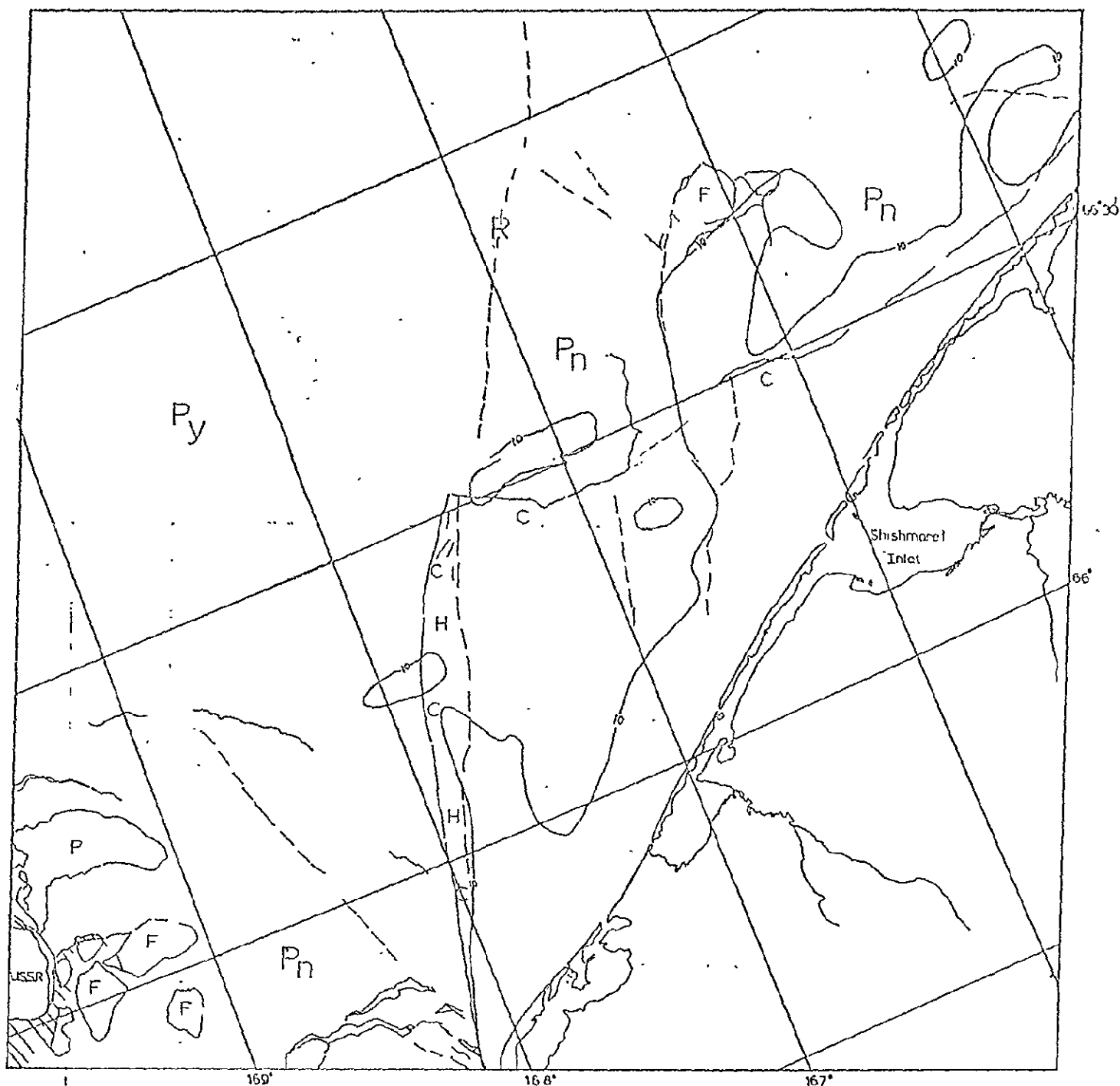
CHUKCHI SEA

E-2384-22003-7

10 FEB. 1976



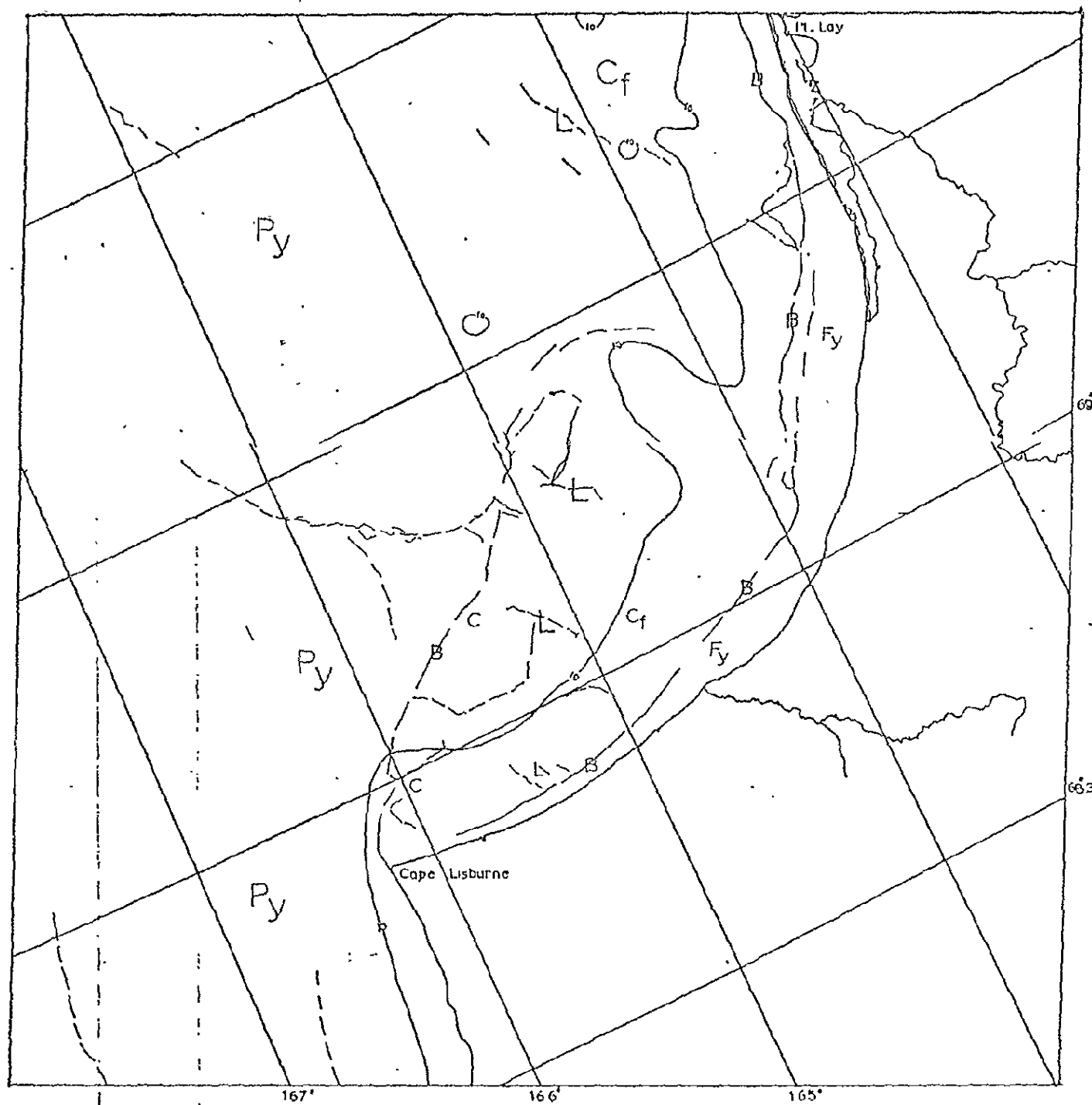




KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

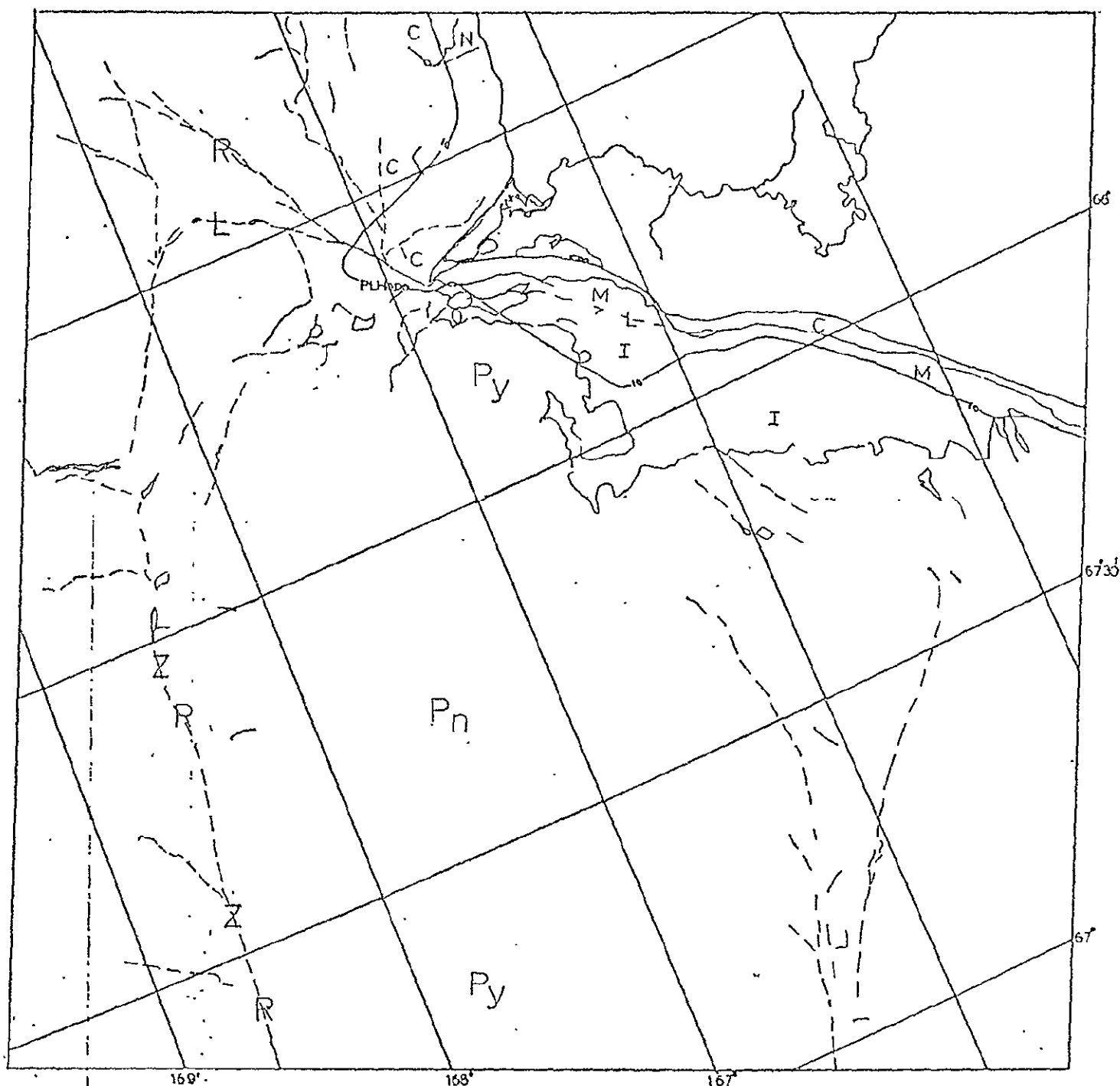
E-2394-22012-7  
10 FEB. 1976



0 10 20 30 40 50  
 KILOMETERS  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

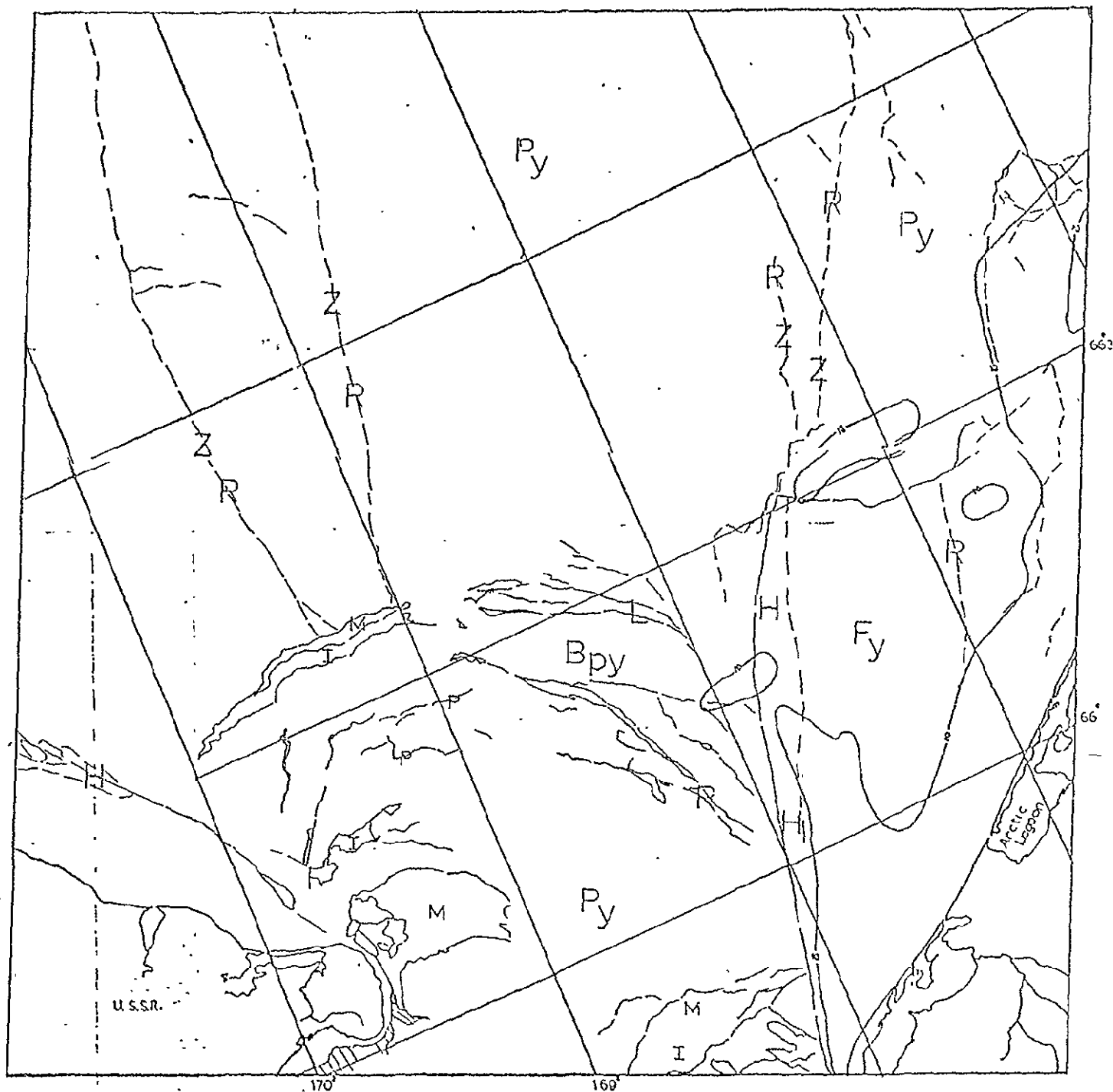
E-23852200-7  
 11 FEB. 1976



KILOMETERS  
 0 10 20 30 40 50  
 SCALE: APPROX 1:1,000,000

CHUKCHI SEA

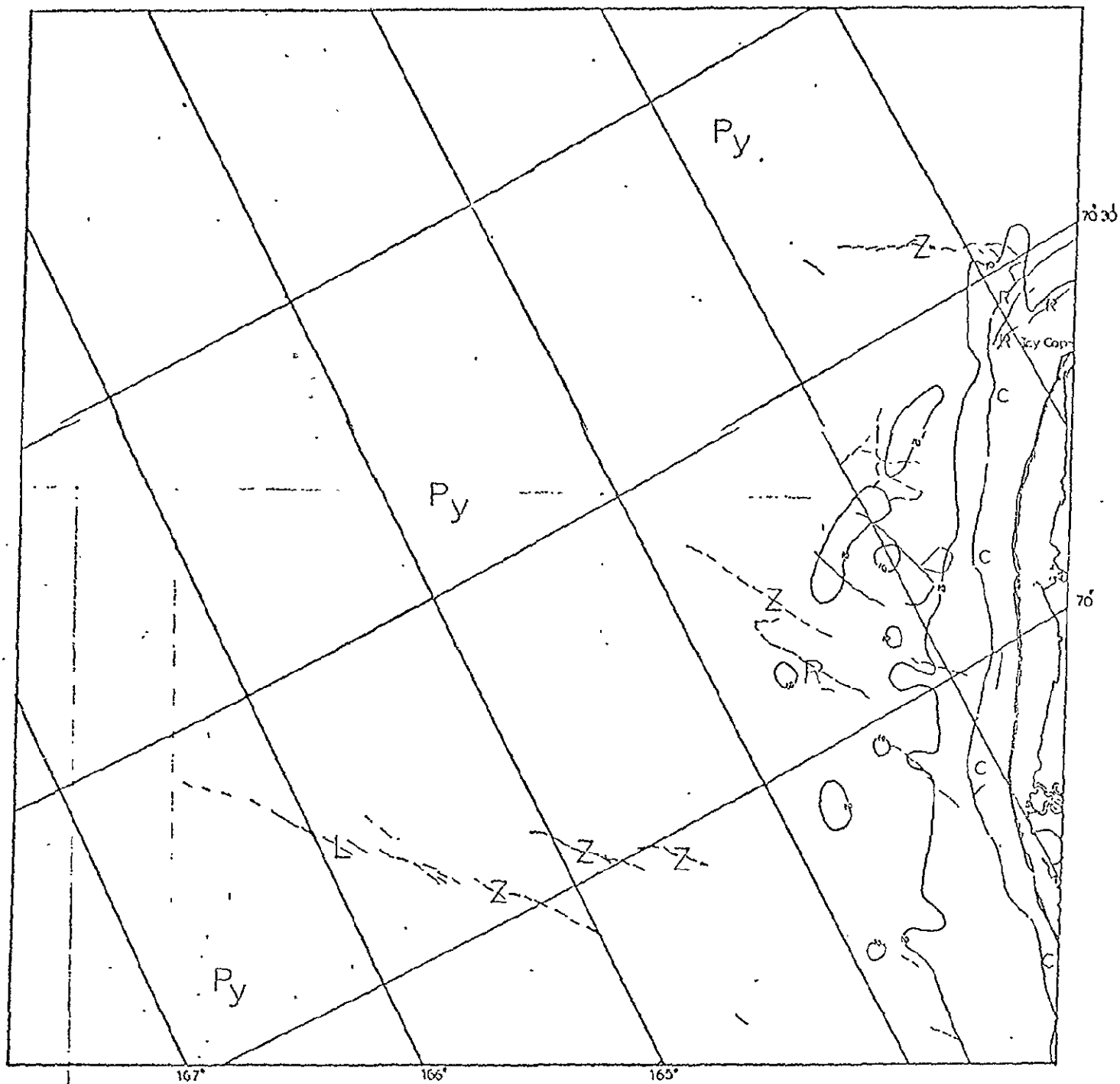
E-2335-22063-7  
 11 FEB. 1970



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E2305-22070-7  
11 FEB. 1976



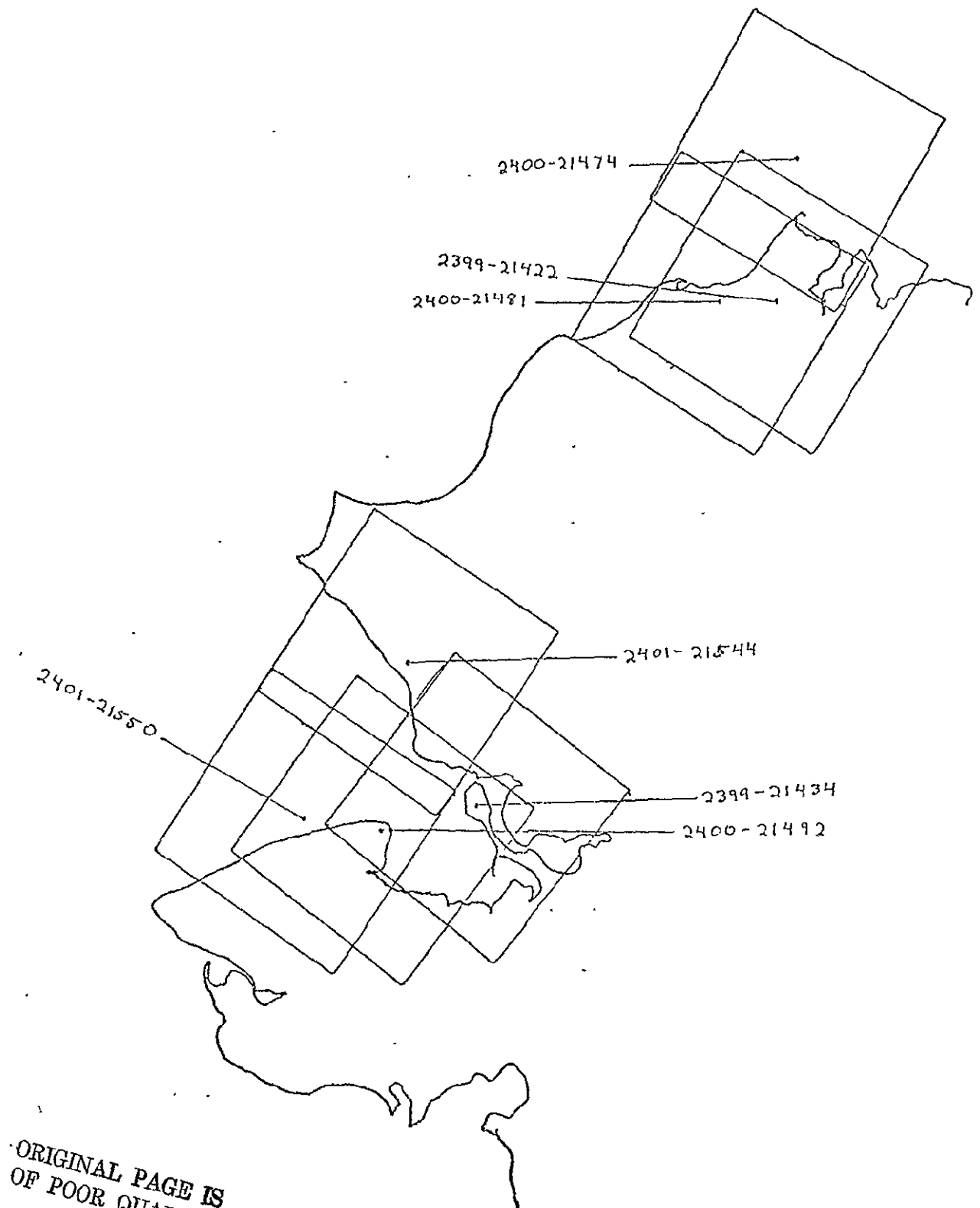
KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2386-22113-7  
12 FEB. 1978

# CHUKCHI SEA

24 FEBRUARY - 12 MARCH 1976  
Cycle 2399 - 2416



ORIGINAL PAGE IS  
OF POOR QUALITY

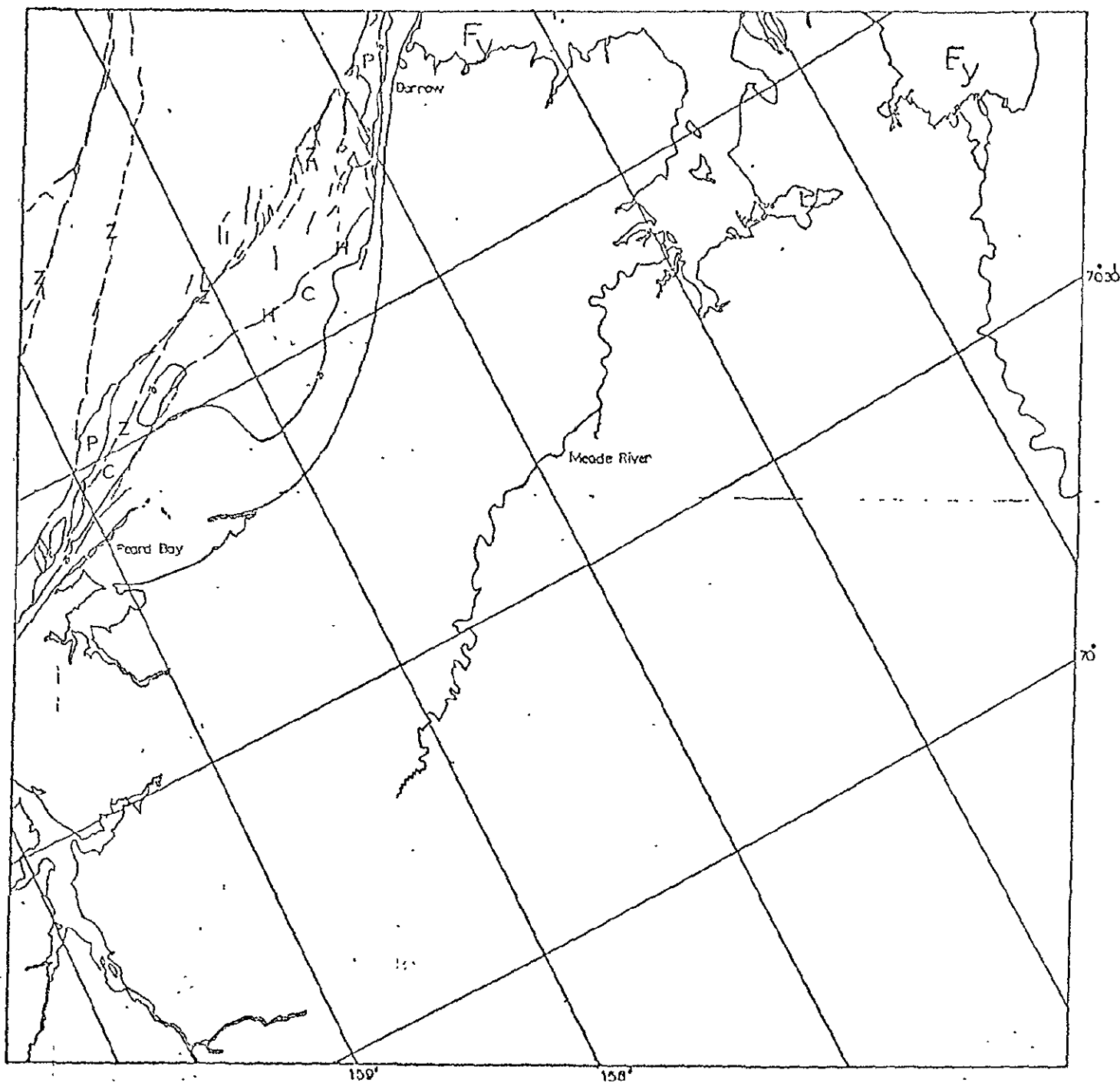
Scenes 2399-21422 } adjacent pair  
          2399-21434 }  
          2400-21474 } adjacent pair  
          2400-21481 }  
          2400-21492  
          2401-21544  
          2401-21550

These scenes show portions of the Chukchi coast between Barrow and Cape Prince of Wales for the period February 25-27, 1976. At this time all ice in Kotzebue Sound including that between Cape Krusenstern and Cape Espenberg is contiguous and well frozen-in. There appears to be a very massive hummock field west of Cape Krusenstern.

Further west, all along the Chukchi Coast, north-south leads are opening up reflecting a WSW motion of oceanic ice. This dynamic event is illustrated in the Point Franklin area where during the one day between scenes 2399-21422 and 2400-21481, a large lead has opened up considerably inshore of the previous zone of shear. The new lead coincides closely with a large ridge system running roughly parallel to the coast.

The new lead system is freezing rapidly and at Barrow has reached the young ice stage. Far to the south the large shear ridge hummock field mapped north of Cape Prince of Wales remains fixed during this event.

ORIGINAL PAGE IS  
OF POOR QUALITY

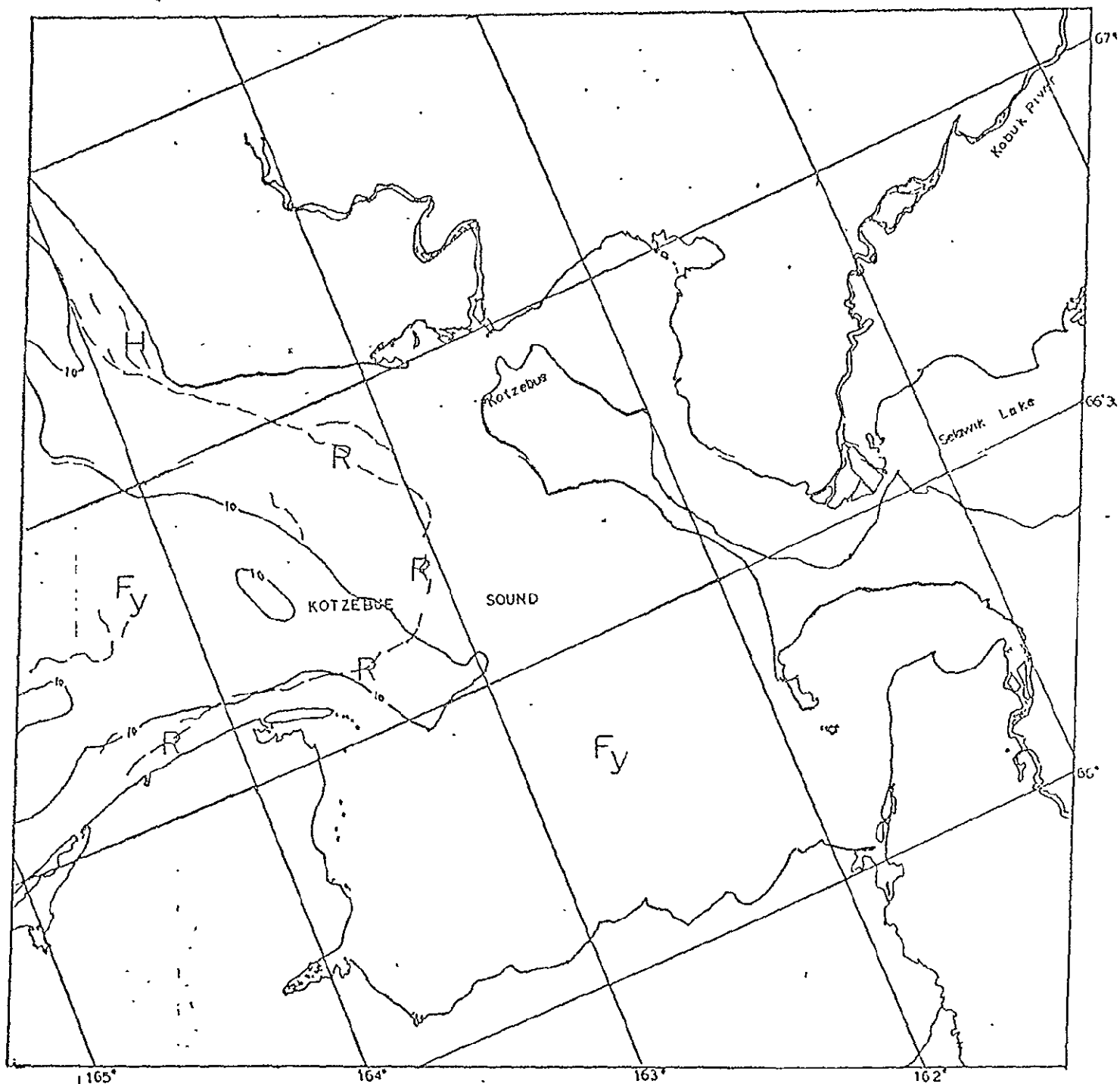


KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2399-21422-7  
25 FEB. 1976

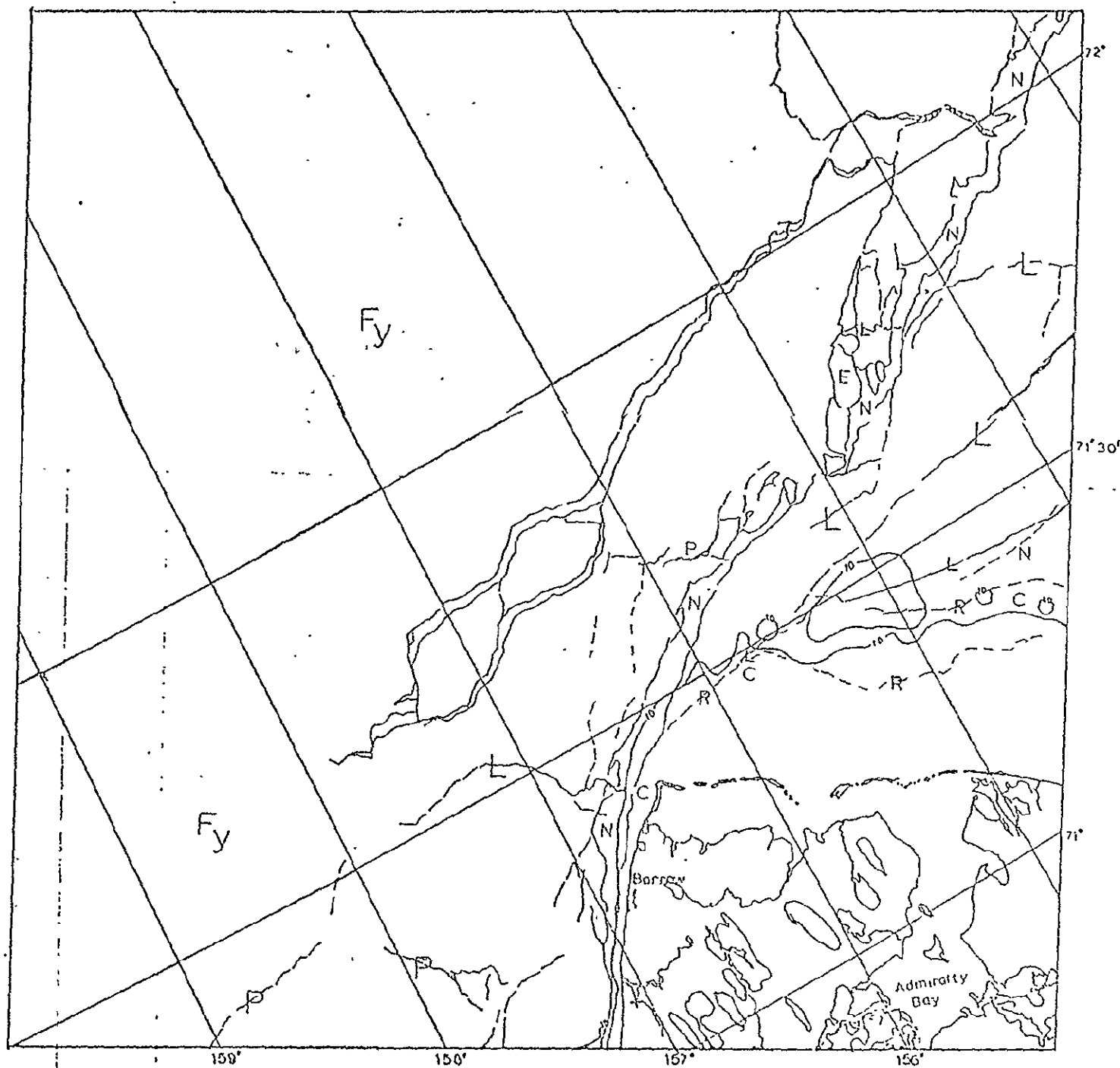




KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

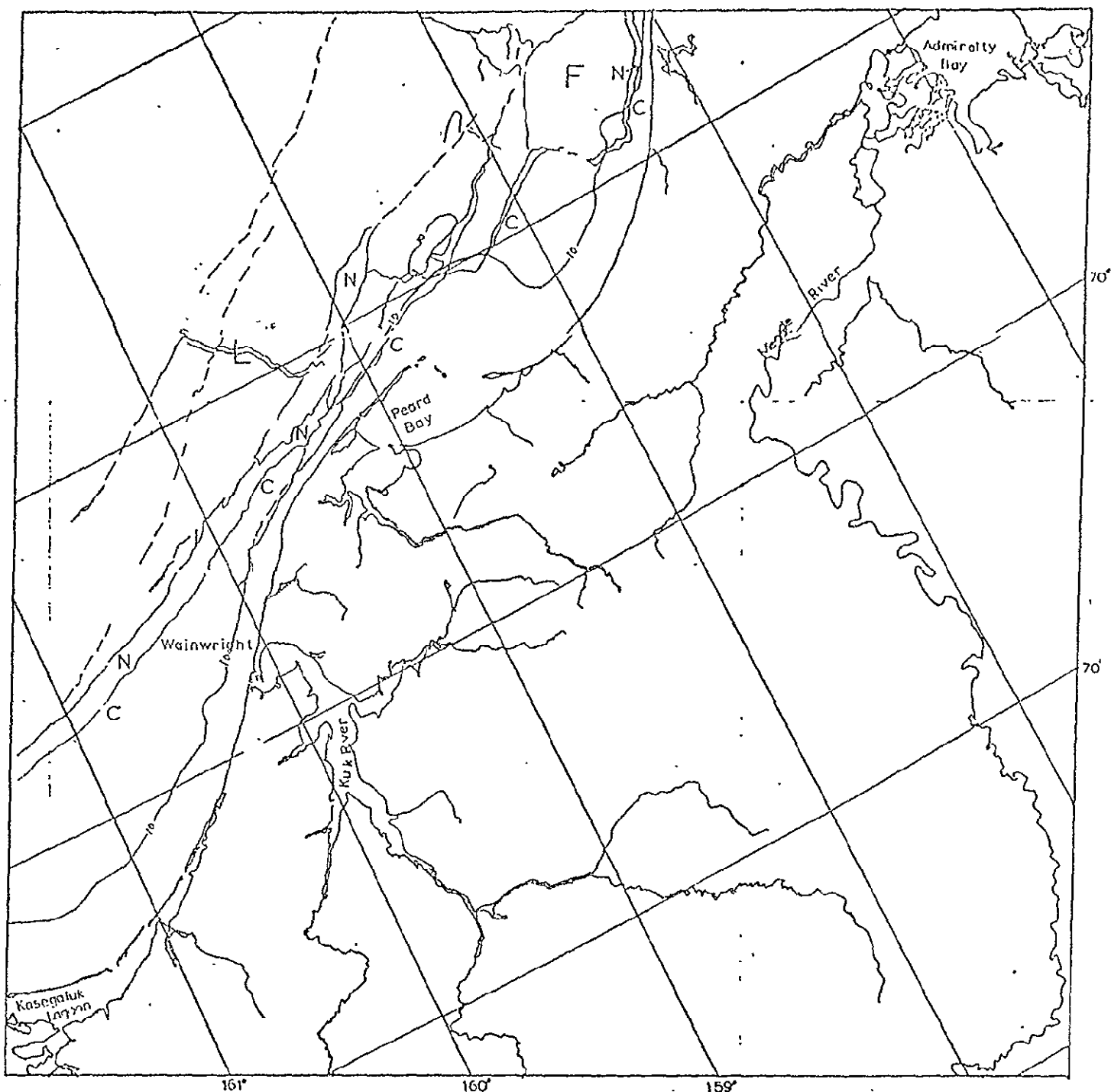
E-2399-21434-7  
 25 FEBRUARY 1976



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

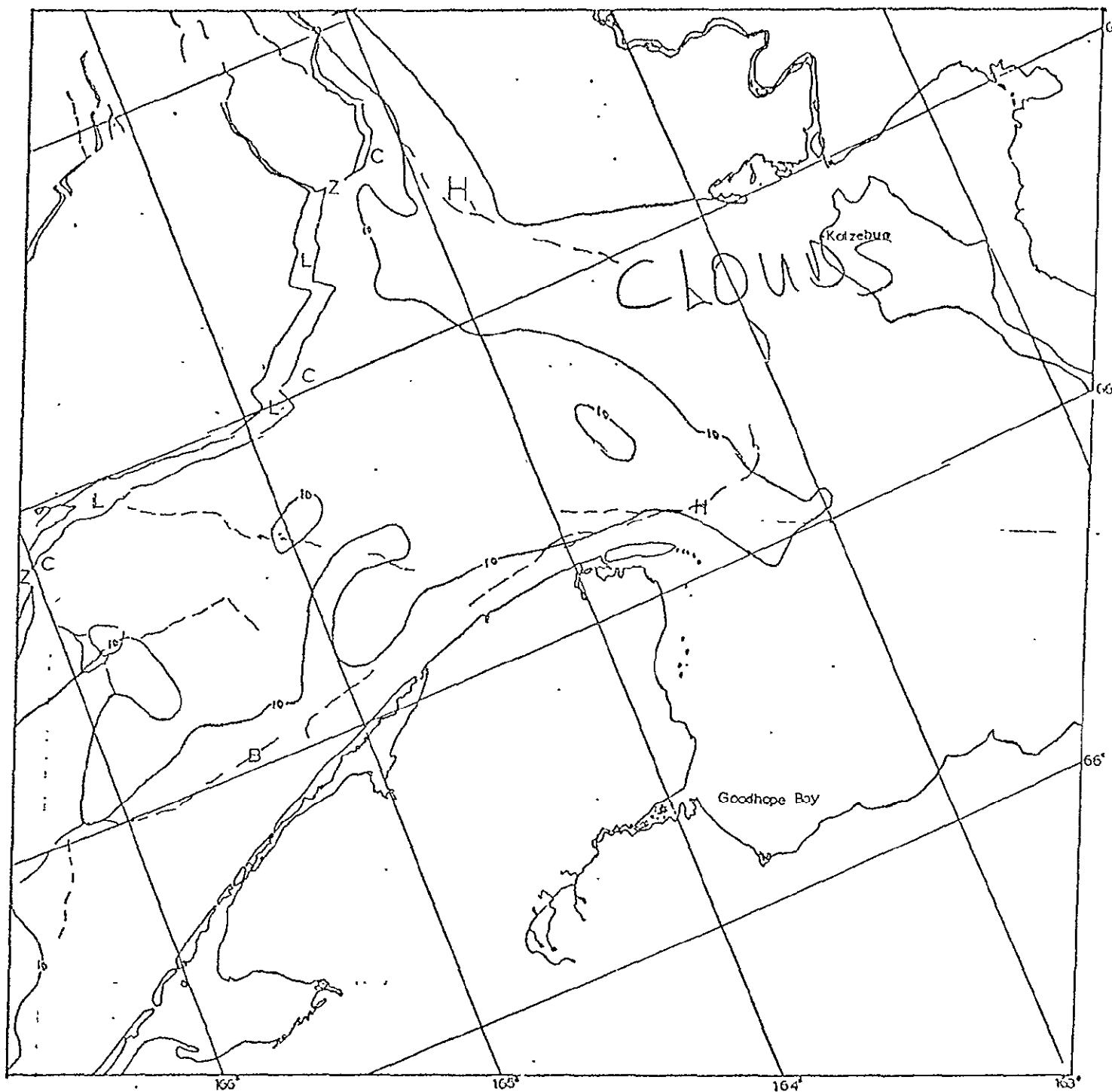
E-2400-21474-7  
26 FEBRUARY 1976



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

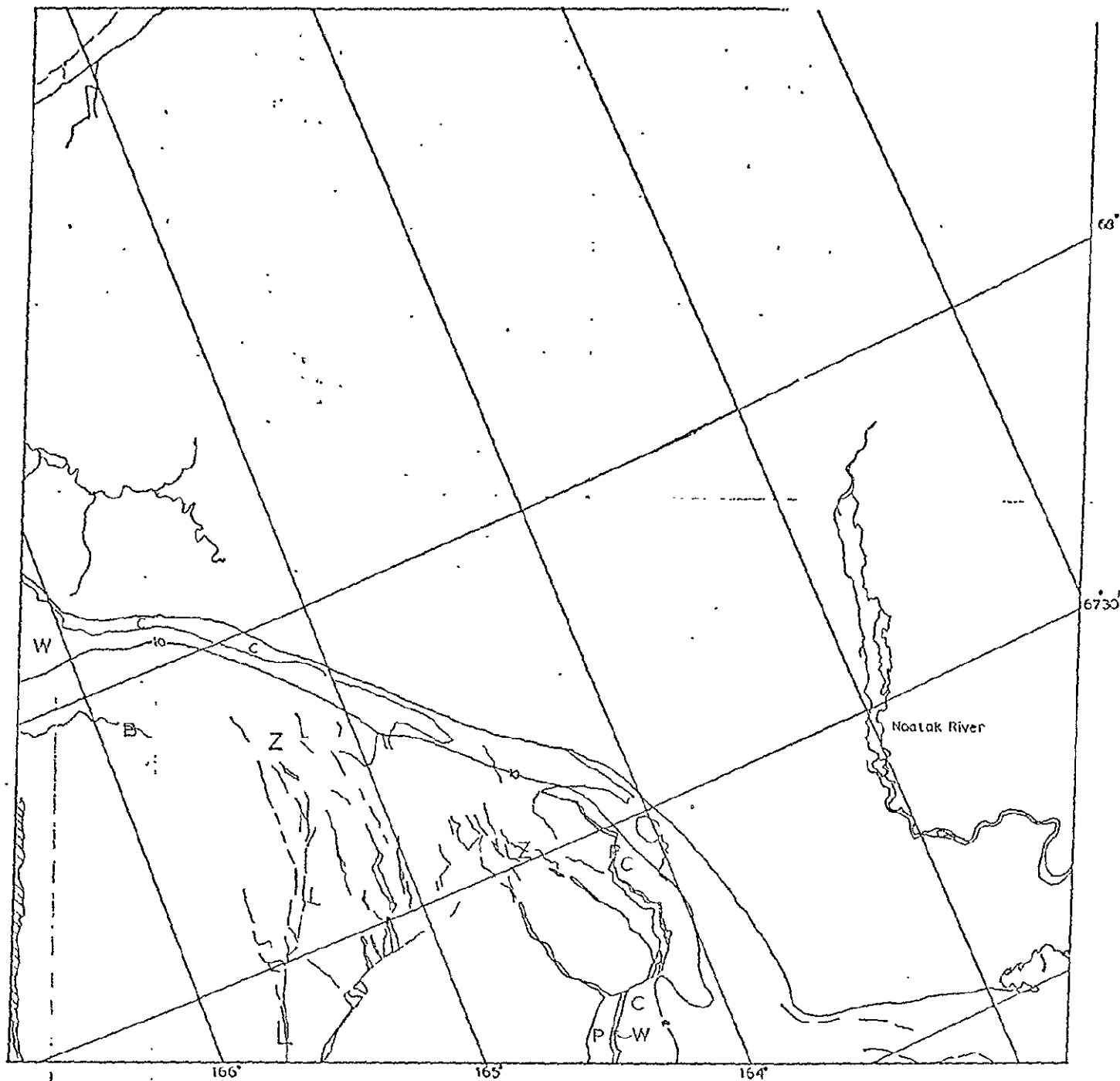
E-2400-21481-7  
 26 FEB 1976



KILOMETERS  
0 10 20 30 40 50  
SCALE APPROX 1:1,000,000

CHUKCHI SEA

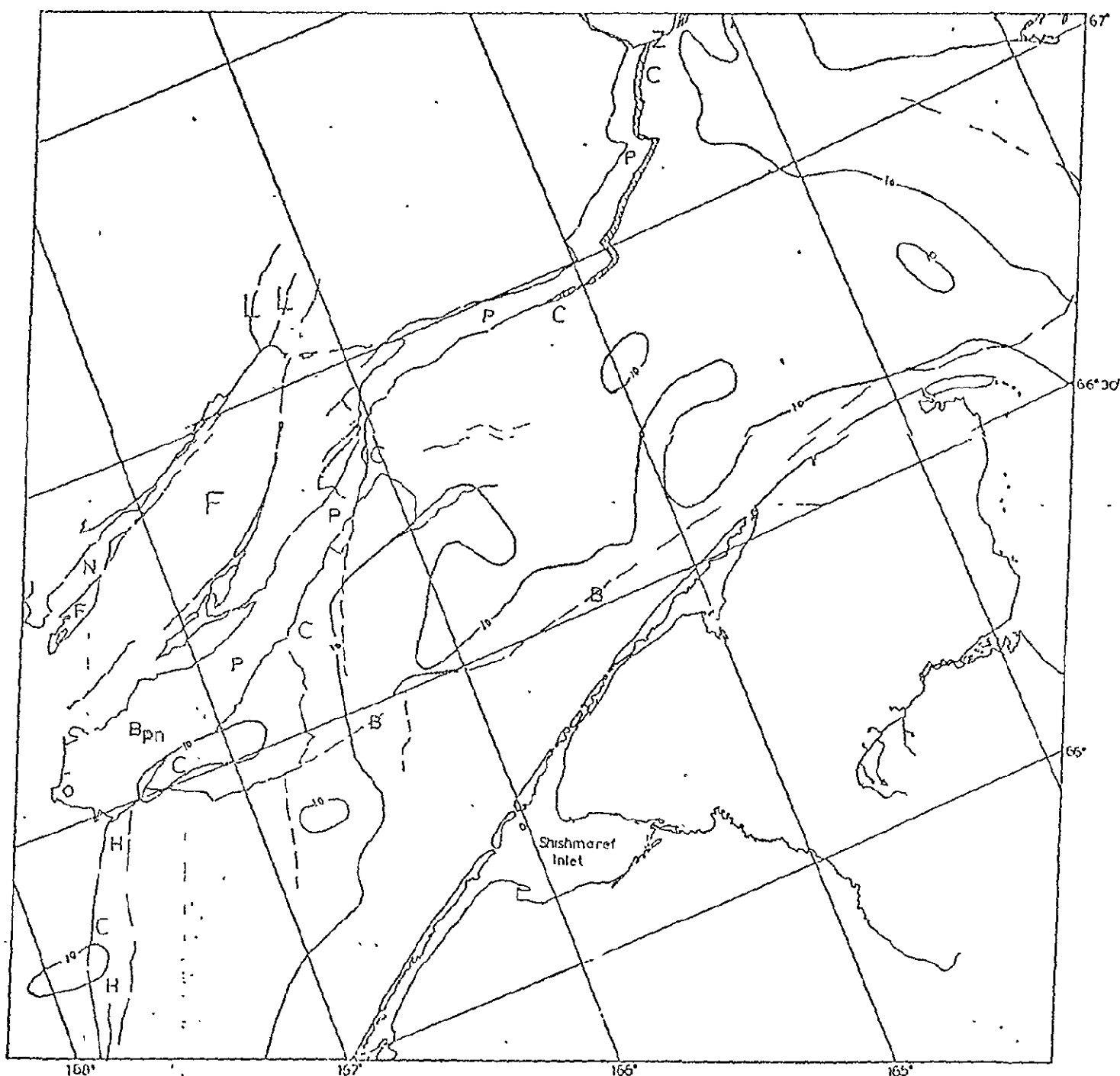
E-2400-21492-7  
26 FEBRUARY 1976



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

CHUKCHI SEA

E-2401-21544-7  
 27 FEB. 1976



KILOMETERS  
 0 10 20 30 40 50  
 SCALE APPROX 1:1,000,000

# CHUKCHI SEA

E-2401-21550-7  
 27 FEBRUARY 1978